EXPERIMENTAL STUDY OF SLEEP

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Dr John

AN EXPERIMENTAL STUDY OF SLEEP

(From the Physiological Laboratory of the Harvard Medical School and from Sidis' Laboratory)

BY

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TO

DR. MORTON PRINCE

in appreciation of his originality in Philosophy and Psychology and of his staunch friendship towards

THE AUTHOR.

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PART I

EXPERIMENTAL

"Hypotheses non fingo"
—*Newton.*

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Chapter I

Introductory Remarks

WRITERS on sleep complain that little attention has been paid to the subject, that it is sufficient to open a text-book on physiology to be convinced of the fact that the physiology of sleep is almost entirely neglected, inasmuch as the school-physiologist usually dismisses the subject with a few phrases, often quite general and devoid of meaning. It is quite true that while one cannot as a rule be satisfied with the imperfect state of textbook-physiology which usually lingers in the hind ranks of the battle-ground of science, still one cannot blame the text-books for avoiding such a delicate subject, the nature of which is so uncertain and so highly problematic.

In addition to the uncertainty of the subject of which the more conservative of school-physiologists fight shy, there seems to be an ill defined feeling which is not without some good foundation, namely, that sleep is not entirely a physiological subject, that sleep presents some very important aspects that need be taken into consideration which the

physiologist is unable to deal with by his usual methods and from his standpoint alone.

Moreover there may be another reason for the indifference of school-physiology to a subject which is otherwise of such a vital importance in the whole domain of animal life. Man is more interested in active than in passive states. It is therefore natural that the physiologist should devote his attention more to waking life than to sleeping states. Besides, physiology dealing essentially with activities and functions tends to ignore states which are usually regarded as the very acme of inactivity. With the advance however of biological, physiological and psychological sciences even states of passivity can no longer be ignored, — their conditions, causation and nature must be studied and closely investigated, especially if those states are found present throughout the ascending line of animal life. The conditions for the study of sleep become all the more favorable as we reach man. We find that sleep-states in man's life are no longer instable and taken by snatches, because the watchfulness requisite in wild-life under the constant strain of the struggle for existence no longer obtains. In man's life sleep-states become more or less organized, systematized and are no longer disturbed, — they alternate rhythmically with waking states. More than one-third of man's life is passed in sleep, — it seems that this fact alone should indicate the importance of sleep-states in man's cycle of biological and physiological processes and should arouse the interest of the scientific investigator. As a matter of fact some scientific thinkers have given the subject of sleep a good deal of their attention. Although text-book physiology passes over the subject with a few meaningless phrases, the literature of sleep is really very extensive. It may be well before we proceed with the exposition of our own observations and experiments on sleep to give first a brief review of the chief theories on sleep.

Chapter II

Theories of Sleep

FROM the very earliest times man wondered about sleep and attempted some explanation of it. It was supposed that in sleep the soul wanders away from the body and leaves it in a lifeless condition. Many of the savage tribes are on that account afraid to waken people lest the soul may be frightened away and not return at all to the body. That is why even at present we often hear the saying that sleep is the companion of death. On the other hand death is often described as sleep. On the same basis dreams were explained by the primitive mind,— the soul in sleep leaves the body and wanders away; on its wanderings the soul meets with all kinds of adventures and it is such experience that gives rise to dreams. In sleep the wandering soul, not encumbered by the gross body, can visit great distances in a short time and can even communicate with heavenly powers,— with angels and gods.

The impassive soul reluctant flies,
Like a vain dream, to these infernal skies.

Modern spiritualists adopt this ancient belief in full or express it as "the release of human personality from the subliminal."

The scientific theories of sleep are numerous, but they can be reduced to a few main types. This reduction will help the reader to become oriented in the vast literature that has gathered about the subject. The theories of sleep may be classified as follows:

1) The Physiological theories, which may be subdivided into:
   a) Mechanical
      and
   b) Chemical
2) Pathological
3) Histological
4) Psychological
5) Biological

The mechanical theories are of the circulatory variety and are usually much favored by physicians,— they attempt to explain sleep by changes in the blood circulation of the cerebrum. As far back as the eighteenth century the theory of sleep greatly in vogue among the physiologists was — congestion of the brain favored by the position of the head. This view was entertained by Haller, J. Müller, Hartley and others. Cappie has somewhat enlarged on it, inasmuch as he ascribes sleep to the venous congestion of the brain. This congestion of blood was supposed to bring about pressure on the brain with the result of depression of all the cerebral functions. The great psychologist Hartley summarises the physiological theories of his time thus: "It appears then that during sleep the blood is accumulated in the veins and particularly in the venal sinuses which surround the brain and spinal marrow. . . . And it is agreeable to this that in most dissections after lethargies, apoplexies, etc., the venal sinuses of the brain and consequently those of the spinal marrow which communicate freely with them are particularly full. . . . It follows therefore that the brain and spinal marrow will be particularly compressed during sleep, since the blood then takes up more space, is particularly accumulated within the cavities of the skull and vertebrae, and the hardness of these bones will not suffer them to yield or make more room. . . . In short this compression will result in sleep." These generalizations were favored by observations on the famous case of the Parisian beggar whose injured skull gave the opportunity to observe the rise and fall of the exposed cerebrum in the waking or sleeping state. Recently Mosso claimed the same causation of sleep and on similar observations. As to the circulatory changes proper, two opposing views have been taken. Some, such as Durham, Cl. Bernard, Kussmaul Howell, Lehman, de Fleury ascribe sleep to cerebral anemia. Others again, such as Brown, Czerny, Broadman maintain that sleep is due to cerebral hyperemia. Claperede in reviewing the circulatory theories of sleep quotes Richet's apt criticism: "Sleep and waking states bring about all kinds of changes in cerebral circulation depending but little on the position of the head. Birds whose hemispheres have

been removed still present the same changes of sleep and waking. Biologically regarded, sleep is a far more general phenomenon than that of the presence of a brain irrigated by a blood circulation. Finally the activity of a tissue is not entirely dependent on the amount of blood circulating in it." There are however still more cogent objections to such theories of sleep, objections which clearly show the incongruence of the circulatory theories. We shall point them out further in our present study.

We may turn now to the chemical theories which are far more favored by the conservative physiologist, inasmuch as they fall in with what the physiologist regards as more scientific. With the experiments of Pettenkofer and Voit on the respiratory quotient new life was injected into sleep theories. Those two investigators have found the respiratory quotient $\frac{CO_2}{O}$ is diminished during sleep. The tissues absorb relatively more oxygen during the day than during the night. This fact of the using up and impoverishment of blood of intermolecular oxygen started new life in the theories of sleep. Pflüger, Sommer and others attempted to work out a scientific theory of sleep based on research of the biochemistry of the cell and the intermolecular activity of the oxygen-molecule or atom. Pflüger's authority lent vitality to this view so that even Heubel whose theory of sleep is really psychological in character tries to shelter it under Pflüger's physiological wings.[1]

With the chemical theories we pass by degrees into the pathological theories of sleep. Already in the early part of the nineteenth century Marshall Hall proposed the view that sleep was a kind of epilepsy. This view however met with little favor, because of lack of facts to support it. With the advance of chemistry and of its application to physiological research, and especially with the rise of the modern views of the rôle of autointoxication and toxins in diseases, the pathological theories of sleep were resuscitated under the new guise of autointoxication. Obersteiner and Preyer launched the theory that sleep was an autointoxication of the system by toxic matters accumulating in the blood, due to the

[1] We may possibly refer to Loeb's work on heliotropism and sleep of butterflies as an example of a purely bio-chemical view of sleep. See Dec. Public Univ., Chicago, V. I.

activity of the various tissues. Lactic acid was supposed to be the particular substance in question. Others such as Dubois ascribed the same state to the accumulation of carbonic acid. These were followed by a host of writers such as Binz, Errero, Bouchard, Breisacker and others. The toxic and autotoxic theories of sleep enjoy quite a wide popularity, because they fall in with the scientific notions of the age. Those theories would make of sleep a pathological state, but the facts are against such a view.

By the middle of the nineteenth century, when physiological experiments on nerve-conduction were at their height, Purkinje proposed the theory that sleep might be due to the interruption of neural conductivity between the cortical matter and the rest of the cerebrum. This view was further developed by Mautner, Warlomont, Oppenheimer and others. As a further modification of the same theory, but based on more fundamental physiological processes may be mentioned Verworn's theory which refers sleep and waking-states to processes of assimilation and dissimilation going on in the organism. At the same time with Verworn, Van Gieson and Sidis worked out their theory of sleep, basing it on similar processes, namely on anabolism and catabolism and developing the interrelation of waking and sleeping states with the symptom complexes of nervous and mental diseases. The theory of Van Gieson and Sidis is based on the variability of different levels of neuron energy. We may dismiss this latter theory in a few words as we shall discuss it in our study. We can only say here that the theory is essentially based on the concept of neuron-energy.

This brings us close to the famous theories of retractility of neuron-elements which have been of late utilized by many writers for various purposes. The development of the histology of the nervous system and especially of neuropathology have brought new life to the solution of the problem of sleep. The biological investigations of the cell by Kölliker, Remak, Nageli, Hoffmeister, Virchow, Max Schultze, Hertwig, Fol, Van Beneden, Strassburger, Heidenhein, Boveri and many others opened up new horizons for theories of cellular activities. Naturally the sleep theories

came in for their share. It was not however until the researches of Golgi and Ramon Y Cajal had laid the foundation for their famous doctrine of independence and contiguity of neural elements that the theories of sleep could seize on some tangible anatomical facts and work them for their benefit. Ramon Y Cajal was the first to advance the view that the neuroglia-cells by their expansions and contractions bring about dissociations and associations of the neural elements with the consequent loss or reappearance of normal waking-states. A somewhat different, but closely analogous theory was launched into the scientific world by Mathias-Duval. Instead of the retractility of neuroglia cells proposed by Cajal, Duval advanced the view that the neurons and their protoplasmic processes are endowed with contractility or retractility and that the functioning and loss of functioning of neural elements are due to contractions and expansions of the protoplasmic processes of the neurons. Demoor, Pupin, Berger and others have enlarged on this hypothesis. At first even Verworn accepted this hypothesis, although he discountenanced it afterwards. Sidis assumed provisionally the same hypothesis for abnormal dissociative manifestations, but refused to accept it as an explanation for the phenomena of sleep which do not warrant the assumption of such hypothesis.

The psychological theories of sleep date from antiquity. The popular explanation is very simple,— it is a description of the phenomena, a description which the popular mind often takes for an explanation of the phenomena in question. Sleep is an abeyance of mental life, sleep is a rest of consciousness. Modern physiologists and psychologists who maintain the psychological theory of sleep have not much improved on that statement. The only modern substitute is that of inhibition. Brown-Sequard, Wundt, Siemens, Forel, Oscar Vogt, all in different scientific phraseology refer sleep to inhibition of cerebral activity, especially of the frontal lobes where mental activity is supposed to "reside," according to some authors. Manaceine in her work on sleep echoes this view and comes to the conclusion that "sleep is the resting state of consciousness." Surely it is an elaboration of the obvious, if one has to write a whole volume

in order to arrive at such an important conclusion. The only one who really made some advance in the psychological theory of sleep was Heubel, Privatdocent at Kiev University, Russia. I can say his is an excellent piece of work based on a series of well performed experiments. Unfortunately, when I started my experiments, I was not acquainted with the work of that investigator. I have gone over in my experimental research a good deal of the same work and may say that Heubel's experiments have been fully confirmed by me. Although Heubel's theory is incomplete, there is a good deal of truth in it and his work well deserves the attention of the student of sleep. His veiw may be briefly summarized in the following statement: Mental activity depends on the incoming peripheral, sensory stimulations; where such peripheral sensory stimulations are absent, mental activity is in abeyance and sleep results. In other words, brain activity depends on sensory activity which in its turn depends on peripheral stimulations. Psychologically stated, consciousness is a function of sensations which in their turn are a function of external stimuli or impressions. In accordance with this view a series of experiments have been carefully carried out by Huebel. As my own experiments were carried out on somewhat similar lines I shall refer again to Huebel's work, when I give an account of my experiments, in order to test a somewhat similar theory arrived at from totally different considerations, viewing the subject of sleep not only from a physiological and psychological, but also from a biological standpoint.

An altogether different departure from the usual theories of sleep was recently taken by Claperède. He points out that biologically regarded, sleep has its significance not as a passive state, but as an active instinct, like all the other instincts of animal life. To put it in his own words: "Le sommeil n'est pas un état purement négatif, passif, il n'est pas la consequence d'un simple arrêt de fonctionnement: il est un fonction positive, un acte de ordre rèflexe, un instinct, qui a pour but cet arrêt de fonctionnement; ce n'est pas parce que nous sommes intoxiqués, ou épuises, que nous dormons, mais nous dormons pour ne pas l'être." This biological view of Claperède forms one of the most

valuable contributions to the theory of sleep. It throws altogether new light on the subject of sleep, and many obscure until now unexplained facts can be understood in the new light of the biological standpoint taken by Claperède. Claperède's physiological theory of inhibition is not as clear, but with some modification I think it could well harmonize with my views and my work on sleep. While accepting the views of Claperède, my standpoint taken in this study is based on investigations published in previous works of mine mainly dealing with the subject of dissociative states in general.

Chapter III

The Conditions of Sleep

TAKING the well-known dictum of Newton, "Hypotheses non fingo," let us start with facts before we attempt to form any idea as to the nature and character of that apparently mysterious state known as sleep. In order to understand a highly complicated phenomenon it is well to study the circumstances under which it occurs and investigate the conditions that favor the manifestation of the state. Now in studying the conditions of normal and abnormal suggestibility, I pointed out in my "Psychology of Suggestion" that the following conditions are requisite to bring about those peculiar subconscious or subwaking states which form the soil favorable for the growth and development of implanted suggestions.

Conditions of Normal Suggestibility	Abnormal Suggestibility
1) Fixation of attention	1) Fixation of attention
2) Distraction of attention	2)
3) Monotony	3) Monotony
4) Limitation of voluntary movements	4) Limitation of voluntary movements
5) Limitation of consciousness	5) Limitation of consciousness
6) Inhibition	6) Inhibition
7) Immediate execution of the suggestion	7)

I have further pointed out that what we really bring about under such conditions is a dissociation of consciousness. In the normal waking state the dissociation is transient, fleeting, disappearing at the very moment of its appearance, while in abnormal suggestibility the states are more or less permanent. In other words, the waking state tends to disappear under the conditions mentioned above. Now to induce sleep the first requirement is the displacement of the waking state. It is evident that the conditions that favor the suppression of the waking state would also favor sleep-states. As a matter of fact I have often observed in my patients and subjects that the conditions by which I intended to bring about a subconscious state in general and a hypnotic state in particular have often resulted in ordinary sleep. I have found quite frequently that the close observation of the conditions of monotony, limitation of the voluntary movements, limitation of the field of consciousness and of inhibition, brought about not a hypnotic state, but ordinary sleep. I began to experiment on myself and found that I could put myself almost at any time into a state of deep sleep by closing my eyes and keeping perfectly still, dismissing all ideas from my mind — closing shop, so to say. I was able to put myself into a quiet, prolonged and often very refreshing sleep. I have further succeeded in the treatment of many cases of insomnia, by following the same lines in bringing about good therapeutic results.

After many years of experimentation and observation I have come to the conclusion that this could not possibly be an accidental matter, but that there must be some close interrelation between sleep-states and the conditions of normal and abnormal suggestibility. In other words, the conviction was almost forced on my mind by the facts that the conditions I found requisite for the induction of dissociated states and for normal and abnormal suggestibility in general play also an important rôle in the induction of sleep.

There is one fact that is specially worth while noticing in the process of falling asleep, and that is, the circumstance that we do not tumble into it in spite of ourselves, that we go about it in a deliberate, may be cold-blooded fashion.

We have to make up our minds and decide whether or no we want to go to sleep, or whether it is best for us to be asleep; and when we decide in the affirmative, we undress and go to sleep. The whole affair is not the after-effect of some narcotic, toxic, autotoxic bodies, nor the result of some involuntary automatic mechanism,— it is a voluntary act,— the result of decision. In this respect sleep is very similar to the abnormal state of suggestibility in which subjects can be artificially put. The state of abnormal suggestibility, the hypnotic state, is not induced by accumulation of toxic products in the system. The state can be brought about at will under the conditions described above. It is a purely voluntary affair, requiring the coöperation of the subject's and the experimenter's attention, active and steady. In fact, subjects whose attention is poor,— imbeciles, idiots, insane persons or persons whose attention is constantly wandering and fluctuating, are extremely difficult to hypnotize. These significant facts so often overlooked by writers on the subject, force on one the conclusion that the psychic factor is of the utmost importance in the formation of sleep-states.

If we now scrutinize the conditions under which drowsiness and sleep occur, we find that they differ in some very important points from those requisite in the induction of hypnotic states. In the bringing about of hypnosis the most favorable condition is the fixation of the attention on some object, perceptual or ideational. So much is this condition of fixation of importance that some writers describe the nature of the subconscious by this one condition of the attention, and characterize the hypnotic state, not without some show of plausibility, as a cramp of the attention. Such a sweeping statement is not entirely true to fact, but it is true that fixation of the attention, steady and persistent, without flinching, constitutes a very important factor in the induction of the hypnotic state. In sleep, however, we observe that the condition is somewhat modified,— it is not fixation of the attention that is conducive to sleep; in fact, fixation of the attention is more favorable to insomnia or to the prolongation of the waking state. What is requisite is a *relaxation* of the attention. If fixation of the attention is present at all, it is only present in so far as it is requisite

to have the attention relaxed, which under some conditions requires either an effort of the will or the presence of specially favorable circumstances. It is the will to give up all active relations, sensory and motor, with the external environment. In hypnosis there is present at first a strained state of attention; in the induction of sleep the strain is practically reduced to its minimum. In the formation of sleep-states all active desire must cease. That is why people with intense, active desires and emotions find it so difficult to fall asleep. On the other hand such intense desires and strong emotional states may, if taken advantage of at a favorable moment, become the best condition for bringing about states of suggestibility, hypnosis and all forms of dissociation. In fact, in this respect we may say that the sleep-states differ fundamentally from hypnotic states. Suggestibility, which is the characteristic trait of subconscious states and of hypnotic states in particular, is absent in sleep-states. While hypnosis and allied states are characterized by a greater facility of reactions to external stimulations, the sleep-states on the contrary are characterized by an almost complete suppression of the more complex reactions associated with mental processes. In other words, in hypnosis and allied states there is a suppression or inhibition of the inhibitions present in waking life; in sleep, on the contrary, the inhibitions are intensified. If put in terms of the threshold theory advanced in my work, "Multiple Personality," we may say that in hypnosis and allied states the thresholds are lowered, while in sleep states the thresholds are raised.

If we turn once more to the conditions of sleep, we find that limitation of the field of consciousness and limitation of voluntary movements play a very important rôle in the bringing about of sleep-states. In this respect Huebel's shrewd observation is correct,— the cutting off of all external stimulations tends to bring about a languid condition akin to sleep. Prisoners in solitary confinement, unless they find a source of mental activity by getting some external stimulations to awaken their mental life, have a tendency to sleepiness. Where attention is relaxed, or the interest in external impressions is gone, there drowsiness supervenes.

In the limitation of voluntary movements a mass of muscular sensations as well as kinaesthetic sensations is kept from pouring into consciousness, the result is a lowering of mental activity, a rise of thresholds characteristic of sleep. The cutting off of external impressions is also of importance in hypnosis, as when the subject is asked to keep very quiet and make his mind a "blank." Where there is a predisposition to states of dissociation the result of limitation is not sleep but hypnosis, with a fall of thresholds.

The most important and possibly fundamental condition common to sleep and subconscious states is that of *monotony*. In order to fall asleep we must dismiss all our interests, all our thoughts. Similarly, to induce hypnosis we tell the subject to try not to think of anything. We impoverish, we make *monotonous*, his mental life by making him think of "nothing in particular."

The fact that people may fall asleep even under intense stimulations is often adduced as a strong objection to the view that diminution of sensory stimulations is conducive to sleep. Thus Richet refers to the fact of "falling asleep at the opera, in spite of the light and the noise." This objection is valid only if we leave out of account the importance of the factor of monotony. It is not so much the diminution of the intensity of stimulations which is of importance in the production of sleep, as the total mass of impressions. In fact, it is not so much the total volume as the progressive, ceaseless variability of the incoming impressions that counts in the keeping up of the restless activity of consciousness in its adjustment to the external conditions of the environment. Given a prolonged stimulation or a series of stimulations of the same intensity, consciousness becomes dulled and sleep ensues. In fact, the more intense the monotonous stimulations are, the deeper is the state of sleep.

It is interesting to note that under such conditions the intensity of the series of monotonous stimulations tends to keep up the sleep-state. With the cessation of the monotonous stimulations the sleep-state tends to disappear. The miller falls asleep under the continuous uniform noise of his mill, and wakes with the cessation of the noise. In

listening to lecturers in a medical school I found how easily the monotonous, uninteresting delivery put me into a drowsy state, and how I came back to myself with a start when the lecturer stopped. Inquiring among the students, I found that their experiences were quite similar to my own; they were kept in a semi-drowsy state by the long-drawn-out sentences, and kept awake by the lecturer's resting-places. Many people who are used to the long, continuous hum of a large city such as New York, for instance, find it difficult to fall asleep in a quiet place.

Chapter IV

Intermediary States

IN many cases where it is requisite to find the causation of the mental trouble, and hypnotization is not possible, I have for many years employed a method which has been giving excellent results, both theoretical and practical. By means of this method, which I have termed *hypnoidization*, I have been able to induce states closely allied to sleeping states on the one hand, and to hypnosis on the other. This work may be regarded as established, having since been confirmed by many other investigators, as well as by my assistants and collaborators in my laboratory.

Basing myself on the conditions which I have elsewhere described for the induction of states of normal and abnormal suggestibility, as well as for the bringing about of dissociated states in general, I have applied the same or similar conditions in cases where hypnosis was not possible. The result was the induction of peculiar states which I termed *hypnoidal*. The hypnoidal state is of an intermediary character, intermediary between the waking state on the one hand, sleep and hypnosis on the other. Here specially lies our present interest in these peculiar states. The patient or the subject while in this state hovers between hypnosis and sleep. Now he may be in a condition which can only be characterized as light hypnosis, and then again to one's surprise the person is found to be in his normal waking state. The state evidently is highly unstable.

The oscillations of the different states may be followed by variations in respiration. Thus the respiration is somewhat unequal in the waking state, becomes quietened and more uniform in hypnosis. When, again, in the hypnoidal state the respiration is slow and with little or almost no variations, it becomes disturbed when the patient passes into waking state, and becomes uniform when he passes into hypnosis or sleep.

The method of hypnoidization shows clearly how the conditions of normal and abnormal suggestibility are utilized and modified in the induction of hypnoidal or intermediary states. I say modified, because it is just on such slight modifications and variations of the conditions mentioned above that the whole matter of hypnoidal states hinges. A quotation from a previous work of mine giving a short description of the methods of hypnoidization and of the character of the hypnoidal state will be opportune here. " The patient is asked to close his eyes and keep as quiet as possible, without however making any special effort to put himself in such a state. He is then asked to attend to some stimulus, such as reading or singing, or to the monotonous beats of a metronome. When the reading is over, the patient with his eyes shut is asked to repeat it and tell what comes into his mind during the reading, or during the repetition, or immediately after. This should be carried out in a very quiet place, and the room, if possible, should be darkened so as not to disturb the patient and thus bring him out of the state in which he has been put. As modifications of the same method, — the patient or subject is asked to fixate his attention on some object, while at the same time listening to the beats of a metronome; the patient's eyes are then closed, he is to keep very quiet, while the metronome or some other monotonous stimulus is continued. After some time, when the patient's respirations and pulse are found somewhat lowered, he is asked to concentrate his attention on a subject closely relating to the symptoms of the malady or to the submerged subconscious state. In other words, the patient is in a hypnoidal state favorable for the emergence of subconscious experiences.

" The patient again may be asked to be very quiet to

move, or change position as little as possible, and is required to look steadily into a glass of water on a white background with a light shining through the contents of the glass; a mechanism producing monotonous sounds is set going, and after a time, when the patient is observed to have become unusually quiet, he is asked to tell what he thinks in regard to his symptoms. In other cases it is sufficient to put the patient in a relaxed condition, have his eyes shut and tell him to think hard of the particular dissociated states."

Now in working with the method of hypnoidization I have often observed in using it that the patient at first tries to concentrate his attention and seems to fall into slight hypnosis, but pretty soon he is fully awake. In closely watching this condition I found that at first the patient attempted to fixate his attention, then lost control over it. His attention being relaxed he fell into a sleep-state, out of which he emerged again, owing to the partial presence of the idea of the necessity of concentration of the attention, as well as to the partial watchfulness present. It is this alternate and incomplete relaxation and concentration of the attention that keeps the patient on the borderland of wakefulness, hypnosis and sleep. In some cases the hypnoidal state passed into hypnosis. Thus in one of my cases, V. F., at first I obtained only hypnoidal states, but after some time the hypnotic state gained ground and the subject passed into typical hypnosis and finally into a somnambulistic state. In other cases I have observed that preliminary to the passing into the hypnotic state proper a short interval is present which may be regarded as a hypnoidal condition. In many other cases the patient is not in the hypnotic condition, but still there are phenomena present which remind one strongly of the hypnotic state.

The close relationship of the hypnoidal state and of hypnosis is sometimes forcibly brought to the mind of the experimenter. Some patients while in the hypnoidal state are observed to become unusually quiet, less talkative, relaxed and after a time distinctly cataleptic. The patient has apparently passed into hypnosis. In most of the cases the hypnosis is of very brief duration. On the other hand, in other cases the subject falls into a sleeping state without

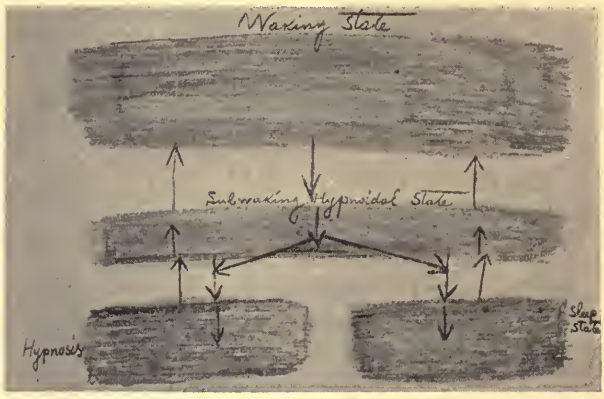
as much as touching on hypnosis. The hypnoidal state is on the borderland of waking, sleep and hypnosis. *Subwaking* seems to be an appropriate descriptive term of the hypnoidal state. Like sleep and hypnosis, the subwaking hypnoidal state greatly varies as to depth and duration: it may range from the full waking consciousness to deep hypnosis. The same patient may at various times reach different levels, so that not all the hypnoidal states are of the same depth; and in that respect they are very much like sleep and hypnosis, which really are not always of the same depth.

What is specially characteristic of the hypnoidal states is the difficulty of fixing them for any length of time,— they dissolve into mist as soon as an attempt is made to seize them,— they are extremely fleeting and evanescent. What specially interests us is the close relationship of the hypnoidal state with sleep-states. The hypnoidal state is the bridge that connects the waking state not only with hypnosis, but also with sleep. To enter sleep or hypnosis one has to pass through the intermediate state, the hypnoidal state.

We may also add that this holds true not only in the case of passing *into* any of the hypnotic or sleep-states, but also in the case of passing *out* of them. A close observation of cases will show that in awakening from hypnosis, as well as from sleep, there is present a short period occupied by a peculiar condition of consciousness, a condition which is no other than the hypnoidal state. It is such states between sleeping and waking, whether on the way to or from sleep, that may be designated as *subwaking*, and are akin to hypnoidal states.

The subwaking states are characterized by the trait of suggestibility. Suggestions are fully possible in such conditions. In fact, in all those cases where hypnosis is impossible or impracticable the hypnoidal states can be utilized for the same purpose. The subwaking or hypnoidal states are utilized by me and by many other investigators in a systematic and methodical way for the obtaining of submerged subconscious experiences. This clearly shows that the subwaking states, while being of the character of sleep-states, are also in close touch with states of dissociation.

One important characteristic of all subwaking states is the formation of hallucinations which indicate states of dissociation under which alone hallucinations can take place. On falling asleep hallucinations crowd consciousness, and on awakening a crowd of phantastic percepts, often giving rise to disconnected dreams, haunt "the halls of consciousness." We may possibly term the intermediary subwaking states leading into sleep as *hypnagogic states* and the dream-hallucinations formed *hypnagogic hallucinations;* the intermediary subwaking states which arise on coming out of sleep we may term *hypnapagogic states* (from ὕπνος, sleep; and ἀπάγω, lead away); the dream hallucinations formed may be termed *hypnapagogic hallucinations.* In passing from waking states into sleep and again from sleep into waking, we pass through those intermediary subwaking states. We may graphically represent those intermediary, transient, subwaking states as follows:



In other words, in going to sleep or rising out of it as well as in entering into hypnosis and its allied states and coming out of them the transitory, subwaking, hypnoidal states are passed through. The subwaking states may therefore be regarded as truly intermediate. The subject in passing through the subwaking hypnoidal states may either fall asleep or pass into hypnosis. Facts thus clearly indicate that sleep-states are closely interconnected with

intermediary subwaking states discovered in my investigation of the subconscious. In the study of sleep then we must devote our attention to the investigation of transitory subwaking states which form the transition between waking and sleeping.

Chapter V

The Induction of Sleep-States

OWING to the kindness of Dr. Walter B. Cannon, Professor of Physiology at the Harvard Medical School, I was given the opportunity and facilities to perform some experiments at the Physiological Laboratory of that institution. I wish to thank Dr. Cannon for all the kindness and consideration he has shown me in the carrying out of the experiments on sleep at his laboratory.[1]

Guided by the work, on account of which was given in the previous chapters, I undertook a series of experiments on the induction of sleep in different animals. I thought it might be well, since sleep belonged to animals as well as to man, to start my experiments on animal life, beginning with lower animals and ending with man. My experiments were carried out on frogs, guinea pigs, cats, dogs, infants and adults. It occurred to me to use the *same methods* to bring about sleep under the conditions of normal and abnormal suggestibility in all those various representatives of the ascending scale of animal life. I consequently tried to induce sleep under the conditions favorable for the bringing about of the intermediary, subwaking, hypnoidal states. Now I pointed out above, that the transient character of the subwaking hypnoidal states was due to the variability of the conditions under which they were induced. Hence the fact of oscillation or instability of such states, the subject now plunging into hypnosis, now into sleep, and then again emerging into the light of the waking state. Hence the mixed manifestations observed in the subjects, when in the hypnoidal state, now presenting the traits of hypnosis and

[1] I take here the opportunity to acknowledge my obligations to Dr. Morton Prince and to Dr. W. B. Cannon for the many helpful suggestions given to me in the revision of the manuscript.

now of sleep. My point therefore was to induce sleep and its allied states, subwaking and hypnoidal, keeping as closely as possible to the conditions of normal and abnormal suggestibility.

Now I found in my experiments on the induction of the intermediary hypnoidal states in man that the conditions of monotony, limitation of the voluntary movements, limitation of the field of consciousness were of the utmost consequence. In my present experiments on animals I followed the same line of work and as far as possible reproduced the same conditions. I tried to limit the incoming sensory impressions, to limit the voluntary movements and thus produce a *monotonous* state by the continuous inhibition of new and varied stimulations. After narrowing down the animal's psychophysiological activity I invariably found that when I succeeded in maintaining closely the same conditions which had been found favorable in human subjects for the induction of subwaking states, the animal uniformly fell into a passive condition closely analogous to the subwaking state and in many instances into a deep sleep. The condition of the animal was often strikingly similar to the one observed in the human subject. The respirations and pulse were lowered, while mental activity in the higher animals, alertness of sensory and motor reactions to external stimulations in the lower animals became greatly reduced and even completely suppressed. In the higher animals, such as dogs, a transitory cataleptic state, a state in which the voluntary muscles retained the position given to them, could be observed accompanied by a disturbance of respiration and heart beat. The slight disturbance then subsided and calmness supervened. The calm lasted but for a brief period of time and the disturbances reappeared. The latter were once more succeeded by calm which ended by full waking state or by a deep sleep. In other words, the experiments, the details of which are adduced further on, allow me to draw the conclusion that I had here the typical manifestations observed under the same conditions in my human subjects. I found here the manifestations characteristic of the intermediary hypnoidal states, the animal now passing into waking and now falling into sleep.

Of course, in the case of the frogs the interpretation of the manifestations is rather uncertain. Still even in the frogs as the course of the experiments advanced the results stood out more clear and distinct, especially when viewed in the light of the experiments performed on the higher animals.

Chapter VI

Experiments on Frogs

It is probably best to begin with the facts and give their interpretation afterwards. It seems advisable to give the reader a clear and full account of my work as a whole, to avoid being entangled in a mesh of unnecessary details. While I experimented on a great number of frogs I present here but a few typical experiments. The reader will thus be in a far better position to get a fair view of the work and be more enabled to judge critically the conclusions drawn from the experiments.

When the frog is put on its back, its lower lid (its only eyelid) is drawn up. If kept in the same position for a few minutes, the frog ceases to struggle and becomes quiet. The lower lid is kept shut, but when the lid is drawn down the frog becomes lively. If the frog is put on its back and stroked gently, the eyes close, the lower lid being pulled up. The frog becomes very quiet, but soon becomes again lively.

The frog was kept on its back for a few minutes; it was held down and its voluntary movements were restricted; it soon became cataleptic. There was a change in the respiration as shown by pneumographic tracings.

A cloth was wrapped round the frog's head. The frog remained very quiet apparently in a very deep "sleep." The eyelids were found drawn up. The same experiments were repeated on other frogs, small and large, and the same results were obtained.

When a cloth is put on the eyes of the frog so as to exclude all light, the frog sinks into a state of rest. It is cataleptic and can then be put in any unnatural position; it does not make any attempt to change its position. The frog reacts but feebly to sensory stimuli; the eyelids are found to be drawn up.

The experiments were then somewhat modified,—the eyelids of the frog were held together with collodion painted over them. At first the frog struggled and was very restless, but soon it became very quiet, apparently sunk into deep "sleep."

The more often the frog is put in that apparent "sleep" or rest-state the easier it is afterwards to induce the same condition.

A big lively frog was blinded. It was easily put in any position, though it would not have retained such awkward postures in its normal healthy state, before it was deprived of sight. It may be well to add that the experiments were performed after the frog recovered from the shock of the operation. The blinded frog could be manipulated far more easily than any other specimen of its kind. It could be placed in any awkward position and would remain so indefinitely until disturbed. No frog with its eyesight unimpaired would have remained for a moment in such awkward uncomfortable positions. The frog, for instance, was hung up by its front limbs on a board, it remained in the same position until disturbed. The frog was put over the edge of a jar where it hung with the front limbs, the body and hind legs relaxed in the jar. It remained in this uncomfortable position until disturbed.

The blinded frog was left in the jar for a few days and then the same experiments were repeated with the same results. The frog was turned on its back, it remained in the same position, as if frozen and turned to stone. The flame of a match was applied to him and he responded to the pain stimuli very sluggishly, but did not turn over. The respiratory and swallowing movements were reduced from 60 to 48 per minute. If left undisturbed, he would remain in the same position indefinitely.

The frog was put in a jar; he tried to jump out of it,—body and forelimbs were outside the jar, but the hind legs remained in the jar dangling. He remained in this position without any change. It seemed as if he fell "asleep" and "forgot" about the jumping out; it reminded one of the story of the sleeping kingdom.

To control the experiments on the blinded frog I took

a healthy frog which was not operated and closed its eyes firmly. It was put in a very awkward position. It remained hanging over the board without any movement for a period of 5 minutes. Respirations became very slow. In this position I could carry it round the laboratory without disturbing it in the least. After 5 minutes it opened its eyes slowly and changed its position.

The blinded frog was put in an upward sitting posture. Its back was supported by a board so that it should not tumble over. In this attitude it remained without change for a long time.

A healthy, not blinded frog, was then taken and after having closed its eyes firmly with my fingers for a period of a few minutes it was put in a sitting posture similar to the one given to the blinded frog. The healthy frog remained, as if stiffened in the same position. Respiration fell to 48 per minute. During the whole period of the experiment the respiration and heart beats were greatly reduced. Response to sensory stimuli was very sluggish; the limbs were in a state of relaxation.

After a few weeks the blind frog was still alive and kicking. It kept very quiet and could easily be put into a cataleptic state.

The blind frog remained in the same position, when left to itself. It remained in any posture given to it. When put over the edge of the jar, it remained in the same position without changing a single muscle. During this time it reacted very sluggishly to external stimulations. Respiration and heart beats were very much retarded.

Similar experiments were carried out by me on a number of frogs with the same results. In some cases interesting effects of inhibition could be observed. Thus in one of the actively respiring frogs with pronounced swallowing movements the latter ceased, when the muscles of the hind legs were seized and sharply and violently pressed or pinched.

Frogs were placed on their backs and then a heavy weight was put on them to hold them for a few minutes in the same position. The frogs soon fell into a cataleptic state and remained in that state even when the pressure was removed. The lower eyelids were found drawn up,

the eyes were partly closed. Some of the frogs when released from the pressure, relaxed their extremities and remained in a quiet state.

Similar experiments I carried out on a number of frogs; the results were of the same character. It is interesting to observe that when the frogs open the eyes and turn to their usual position they remain for some time very quiet.

There is one point to which I want to draw special attention and that is the significant fact that when the frogs are put in the cataleptic condition, and are from time to time restrained from righting themselves to their normal position, they finally fall into a very quiet state,— the limbs are relaxed and remain in a relaxed condition, the respiration and heart beat are greatly reduced and there is little response to external stimulations to which, though of slight intensity, they would have responded in their normal "waking" state by jumping away. In this respect I can fully confirm Huebel who pointed out this fact in his excellent work on the frog.

When I carried out the above experiments on the frog, I was unacquainted with Huebel's remarkable work. I was glad on reading that observer's experiments to find that the work done by me did not stand by itself, but that I had struck a path which had been trodden by a previous explorer having a similar goal in view. Now when I began my experiments on frogs I hesitated to speak of "sleep" in frogs. When however I continued my experiments, I could not help coming to the conclusion that there are such states as sleep in frogs and that those states can be induced under conditions very similar to those we had found in human beings. Still I greatly hesitated to term the states induced in frogs "sleep;" I termed them "rest-states." I had however a lurking suspicion that they might really be of the nature of sleep-states found in human subjects. I was therefore glad to find that Huebel had fearlessly and unhesitatingly described those rest-states by the term we describe similar states in human beings,— namely, sleep. I then took courage and walked with less hesitation and with more confidence on a path that had been unfortunately left untrodden and neglected by the foot of the scientific explorer.

I must, however, add that I am not quite so sure as Huebel is that the "rest-states," induced in the frog and described in my experiments, are sleep-states, but I do think that they are closely analogous to what we regard as sleep-states in the higher animals.

Without knowing of Huebel's work I came pretty nearly to the same results. I observed as Huebel had before me that frogs after they had been put in the characteristic cataleptic condition described by investigators, such as Czermak, Preyer, Danilewsky and others, that the frog passed into a quiet state, the limbs, though keeping apparently the same position, really not being any longer cataleptic, but rather relaxed, that the respiration and heart beats were greatly lowered and that if the frog could be left in this state without any disturbance, it would remain in that quiet condition for a very long time.

I did not observe as Huebel did that the frogs put in such states remained in it for over five hours, but I did observe that if the environment and external stimulations could be kept quiet, the frogs would remain in their passive states for a very long time. Unfortunately, the place where I worked was rather noisy; in fact unusually so, for the successful carrying out of such delicate experiments. I should not wonder then that I could not fully get all the results that Heubel got who was working under more favorable conditions. I am not quite ready to claim that the passive states in which the frogs fall are really sleep-states, a claim defended very strongly by Heubel, but I do favor Heubel's statement and think that the states of the frog, *after the cataleptic state has passed*, is very much like what is usually regarded in the higher animals as sleep.

Now if we scrutinize more closely the series of experiments carried out on the frogs, we find present the conditions of monotony and of limitation of voluntary movements as well as of limitation of what may be regarded in the frog as consciousness, or of the limitation of the activity of the sensorium by cutting off the regularly incoming sensory stimulations. As a result we find something analogous to what we should have expected in the human subject under like conditions, namely, the presence of peculiar passive

states,— that is all that we are thus far justified to say of them, observed and described as they are by experimenters who do not have the possibility of getting the subjective experience of the animal under observation.

What we find in the state of the frog is a condition somewhat analogous to what we have found in our experiments in human subjects, namely the *presence of intermediary states of the subwaking or hypnoidal type.* The symptoms observed differ somewhat, but in general they may be regared as alike. We find a passive state with cataleptic manifestations. The state varies from catalepsy to relaxation or what may be regarded as lethargy, and again from passivity to activity, from sluggish to very lively reactions in response to external stimulations. We have therefore here, manifestations which remind one of like manifestations in the human subject, namely subwaking, hypnoidal states which are on the borderland of waking, hypnosis and sleep. Of course, we should not expect to find that frogs which stand so low in the scale of vertebrates would manifest phenomena of the same character as the higher vertebrates, but we should expect that some similar phenomena, though otherwise widely different, would be present. This is precisely what we find in the frog. We find the *general* characteristics, though rather vague, of what is afterwards fully developed in man as the subwaking, hypnoidal state.

We must remember besides that the hypnoidal state is very unstable and its manifestations, having the characteristics of waking-state, sleep and hypnosis, greatly vary in different individuals and at different times in the same individual. We should therefore expect that the hypnoidal state would show still more radical differences from the typical in the various species of animals, especially in those that stand so far apart from each other as frog and man. What is surprising to me is not the fact of the variation and great difference of the hypnoidal state in the frog as contrasted with man, but that the difference is really not far greater, considering the gap that exists between the two organisms. In fact, the similarity is far more striking than is the difference between the hypnoidal states of the two

contrasted organizations so widely apart in the scale of evolution.

My view then is that *the phenomena observed in the frog are hypnoidal in character.* The phenomena themselves as well as the conditions under which they are induced warrant my view of the hypnoidal nature of the states.

In this respect we can well understand the apparent disagreement of the early observers on the subject. Czermak and Danilewsky regard the phenomena as being of the hypnotic order, Heubel regards them as being more of sleep-states, while Preyer views them as being the results of fright which give in the waking-state cataleptic manifestations closely similar to those observed in hypnosis. Verworn who regards the phenomena as "Lagecorrectionen" due to central inhibitions really does not conflict with any of the views. It is simply a general physiological hypothesis which may be in accord with any view, a physiological hypothesis which may or may not be true; it is a hypothesis far removed from the special facts and should be tested on its own merits. My point of view is not a matter of hypothesis, but describes and explains the phenomena in terms of states having similar manifestations and produced under the same conditions, states which are more developed and stand out more pronounced in higher animals. These states possess many of the characteristics of the waking state, sleep and hypnosis. Hence the reason why the early observers regarded the phenomena as waking states, as Preyer did; others regarded them as hypnosis, a view maintained by Czermak, Heidenhein, Danilewsky; while other investigators regarded the phenomena as sleep-states. As a matter of fact the phenomena and the conditions under which they are induced make the view highly probable that the different investigators are not far away from the truth, but not being acquainted with the peculiar hypnoidal states described, they observed the phenomena in too one sided terms, in terms of sleep, or hypnosis, or of waking-states. In reality the phenomena and the conditions under which they are induced point strongly to the fact that the states are hypnoidal in character, states which partake at once *of all the three apparently contradictory manifestations,— waking,*

sleep and hypnosis. Now the manifestations of the waking-state, and now the symptoms of sleep, and now again of hypnosis predominate. In short, the state induced in the frog under the conditions of monotony, limitation and inhibition is a *variety of the subwaking, hypnoidal states*. This induced hypnoidal state being intermediary in character may either partake of the catalepsy of hypnosis strongly modified and manifesting itself differently in the frog than in the human subject, or may again go over into the passive state of "sleep" or some state analogous to it.

It is perhaps of importance to call attention to the significant fact that the first stages induced in the frog are rather of an unstable character,— the frog when put on its back and kept down for but a short time falls into an apparaently cataleptic state of short duration. The animal soon rights itself and is fully awake as before. This instability is very characteristic. Now the hypnoidal states are just characterized by this fundamental trait of instability. It is only when the condition of monotony, limitations of voluntary movements and inhibition are sufficiently prolonged that the catalepsy becomes more or less fixed for some period of time, and when this passes off, and the conditions under which the frog is kept are continued still further, it is only then that the frog sinks into a passive state which may last indefinitely, unless brought out of it by some strong stimulation. It seems to me then, that if we take all this into consideration, we cannot possibly describe the state in which the frog is put in other terms than what we have on other occasions discovered to be the intermediary, subwaking, hypnoidal state.

Chapter VII

Experiments on Guinea-Pigs

WITHOUT going into physiological speculations let us once more return to our facts.

In the pathological Institute of the New York State hospitals, I had occasion to carry on a few experiments on guinea-pigs. One of the guinea-pigs was put into a cataleptic condition by gentle stroking, while another was put into a similar state by simply seizing him suddenly. The guinea-pigs lost the control of their extremities and could not move even when stimulated by strong electric currents. After a few minutes left in the same position the guinea-pigs recovered the use of their extremities. The holding down of the animal to one position of the limbs, the gentle stroking, or the strong emotion of fear favored the condition of monotony and inhibition. In my present experiments I tried something similar, namely, to put the guinea-pig under the same conditions of experimentation under which I put the frogs and my human subjects.

A guinea-pig was bound with straps and plaster strips and was left in this condition over night. In the morning he was found in the same place,— he could not free himself. He was very much weakened and paralyzed. He did not struggle much and could easily be put into a passive state. Unfortunately it was hard to say whether the passive state was due to his weakness or to the conditions under which he was artificially put.

Young guinea-pig, of a few days old; very lively. I took him in my hands and kept him quietly and then put a blind on his eyes as I did in the case of the frogs. At first he struggled, then became very quiet. Respiration fell from 120 to 90 per minute. He remained in the same posture for about 35 minutes. He did not respond to stimuli such as intense noises. After fifteen minutes respiration was regular and fell to 60 per minute. The guinea-pig looked like a ball of immovable matter,— the

only thing indicating life was the regularity of the respirations. After a few minutes I found that he started at intense stimuli, but still did not change posture. As he was near the end of the board his foot slipped from relaxation of the limbs, he changed posture, but remained immovable. After half an hour he began to stir and move his head slightly.

On closing the pig's eyes there was a difference in respiration,— the respiration fell and became more uniform.

I tried now to modify somewhat the experiments. I found that the pigs were extraordinarily lively animals and struggled a good deal. Now in my experiments on human beings where there was too much opposition to the induction of subwaking states, I could reduce the opposition by the use of hypnotics and anaesthetics. I tried similar experiments on my frogs, but the results were not satisfactory. The anaesthetized frogs either reacted very much like normal animals, or when given a somewhat larger and more effective dose soon died. I attempted to paint the skin of the frog with collodion to exclude stimulations of the skin, but the frogs died in convulsions. When I soaked their skin in chloroform or ether I had the same results. Evidently the skin of the frog absorbed the chloroform or ether and produced undesirable poisonous effects. Since however I did have success with my human subjects under similar conditions, I thought I might have some favorable result in the case of the guinea-pigs.

A guinea-pig was put under chloroform for a few seconds. Respiration fell to 48 per minute. Reflex movements were well preserved. Eyes were partly closed. The guinea-pig started every time, but did not react to sound or light-stimuli, and very sluggishly reacted to pain-stimuli. He shivered and then closed his eyes. About 15 minutes later he began to react to stimuli. The reactions conformed to Pflüger's law[1]. Stimulations called forth reactions on the same side. About half an hour later the pig began to feel pain, cried on sharp pinching of the front paw. Respiration was still greatly reduced. By closing his eyes and by continuous gentle stroking of his back, it was easy to make

[1] See p. 87, footnote.

him fall asleep. He rolled up in a ball and seemed to sleep quite comfortably.

Guinea-pig under ether for about a minute. Respiration and heart-beat greatly lowered. Muscles were relaxed; eyes were half closed in sleep. Later on he awoke and was fully alive to external stimulations, though not so lively as usual. I put him in my hand, kept him very quiet and closed his eyes. He evidently fell asleep as he did not open his eyes when I removed my hand from them; on the whole the pig kept unusually quiet without stirring a muscle.

A guinea-pig was put under ether for 30 seconds. Reflex of wiping with forepaws was present. Reactions to stimuli were rather sluggish. After a few minutes the pig awoke, but had a tendency to go to sleep again when I put him in my hand, kept him very quiet and closed his eyes. He fell into a quiet sleep, his muscles relaxed; respiration and heart-beat were much lowered. When disturbed, he became fully awake and began to eat, but went immediately to sleep again, when put in my hand and kept quiet. Now and then a passing state of resistance of limbs was observed. The limbs once changed often retained the posture given them. This state however was far from being as marked as it was found in the case of the frog.

When light was excluded from one of the eyes of the animal the other eye began to contract and close; the animal became unusually quiet. Anything that excluded visual sensory stimuli and brought about limitation of the voluntary activity of the pig produced a state very much akin to sleep with now and then a slight catalepsy quickly followed by relaxation of the limbs.

A guinea-pig was fixed on a board,— he kicked violently. Collodion was used to fasten his eyelids together and as in the case of the frog, he became quiet and ceased to make attempts at fighting.

A guinea-pig breathed chloroform for two seconds only. It seemed to have affected the animal sufficiently to make him quiet. He did not fight; lost a good deal of his liveliness. I put my hand on him, restricting his movements. He did not resist; I then closed his eyes; he remained without stirring in the same posture.

When I closed one eye of the animal, the other closed also and the animal seemed to have gone to sleep, the limbs being in a relaxed condition.

After some time he opened his eyes again; chewing movements were present; active, lively and restless, sniffing about in all directions. I once more took him in my hand, kept him very quietly, but firmly,— his activity subsided, he ceased to struggle, eyes became contracted as well as pupils; finally eyes closed very slowly. The animal sank into a state of torpitude. Respiration and heart-beat fell.

Thus far we may say that the experiments on guinea-pigs gave results somewhat similar to those of the frogs, though the cataleptic states were not so pronounced,— in fact they were very transient. Still the induction of sleep was brought about under conditions of monotony, limitation and inhibition. It was far more difficult to bring about rest or passive states in guinea-pigs than in frogs, on account of the great liveliness and ceaseless activity of the pigs. It may be objected that the anaesthetics somewhat modified the result, because it might be claimed that the sleep-states induced were really due to the anaesthetics used. This objection however can be easily obviated by the rejoinder that the action of the anaesthetic was only to reduce the extraordinary activity and restlessness of the animal and thus make it easier to induce sleep. The sleep-states themselves were really produced under the same conditions as were the ones induced in frogs and in my subjects. In fact even when the guinea-pigs were really lively and active it was sufficient to subject them to the conditions described, when they gradually fell into a state very much of the character of hypnoidal states and sleep. The phenomena though were not so well marked as in the frogs.

Chapter VIII

Experiments on Cats

In passing now to my experiments on higher animals the results seem more striking and convincing. As in the case of the frogs, I can only quote some of the experiments performed, it would take up too much space of the present paper to quote all of them. Besides little will be gained by a literal transcription of my note-book, since many of the experiments are simply repetitions of one another. I shall bring as many facts before the reader as will sufficiently introduce him to the work and make him so familiar with the experiments performed that he may be enabled to follow closely the various threads that go to form the main strength of the present research.

A young kitten of about six weeks, very lively, runs about playfully, wide awake. When put on its back, it struggled violently. I then put the kitten in a cloth, kept it firmly so as to limit all the struggles and voluntary movements. At first it struggled and fought, but I restrained the kitten as much as possible, and then I closed its eyes for about a minute. The struggles ceased gradually and the kitten passed into a passive state of sleep. When I relaxed my grip on its body, it remained in the same position without moving a limb. At first the respirations went up and also the heart-beats. But as the kitten became more passive and went into deep sleep, the respirations and heart-beat fell. The kitten was deeply asleep, did not react to sound stimuli or to light; eyelids were firmly closed. At first a slight resistance in the outstretched paws, strongly suggestive of hypnotic catalepsy, was observed, soon the paws were fully relaxed and easily changed to any position, but without retention of impressed posture. The sleep lasted for more than twenty minutes and would have lasted longer, had it not been for the fact that I disturbed the kitten's repose to continue my experimental work.

The same experiments were repeated again and again under the same conditions of monotony, limitation of volun-

tary movements and inhibition. The results were uniformly the same. It may be well to call the reader's attention to the fact that holding the kitten down firmly, thus limiting its voluntary activity, is really at the same time conducive to greater monotony of peripheral sensations coming from the action and movements of the muscles, joints, synovial surfaces and so on; so that the factor of limitation largely aids the condition of greater monotony. Although the pressure exercised on the animal during restrictions may be intense, still, as we have pointed out, it is not so much the intensity of the sensory mass which keeps up the waking state, as the manifoldness and the volume of sensations and reactions ceaselessly varying from moment to moment as to quantity, quality and intensity.

The kitten was restricted in its movements; it was held down for some time, but it did not go easily into a quiet state. I found that the best arrangement was to enwrap the extremities, the hind extremities at least, in a cloth. This limited the voluntary movements effectually. It was still easier, when *all* the extremities were enwrapped in a cloth. When now I put my fingers over the kitten's eyes and closed them, there was little resistance and in a few seconds, not more than half a minute, the little thing was extremely quiet and in a minute or so it was fast asleep. The fingers were then removed, the kitten's eyes remained firmly shut. In fact, the eyelids resisted all efforts to open them. When forcibly opened, the eyeballs were found rolled up and the pupils were contracted. The kitten would have probably kept on sleeping for some time, if judged by what had been observed in other kittens under similar conditions, had it not been disturbed in order to have the experiments repeated.

The kitten was snugly put away in a cloth, and all four extremities were restricted from voluntary movements. At first the kitten struggled a little, but was soon quieted. I then shielded the kitten's eyes with my hands, while I held it firmly for a few seconds only. The kitten's eyelids became half closed and finally closed fully. When the extremities were tested immediately, they were found resistive and slightly cataleptic. Occasionally the resistance was quite marked.

The cataleptic state was rather transient. In some experiments I even succeeded in raising the paws into uncomfortable postures where they remained without change for a brief period of time. After a few seconds the catalepsy of the extremities passed off and the limbs were in a state of relaxation. The kitten did not react to stimuli, such as sound, light or smell; even slight pinching, change of the extremities, shifting of the posture of the body did not produce any reaction. When aroused from sleep, the kitten yawned and stretched its paws, looked sleepy and reacted sluggishly to external stimulations.

Kitten struggled hard when put on its back. It was enwrapped in cloth and still kept on its back, where it was held firmly without being allowed to turn over or even to move. I then closed the kitten's eyes. After a minute it remained in the same position. The kitten was lying quietly on its back, though the position was rather unusual and the whole attitude was very uncomfortable. The paws were raised in the air and at first there were manifestations of resistivity about the joints, but soon the resistivitv passed off and the limbs, though raised, were really soft and relaxed. A little later the paws dropped slowly and remained in a state of relaxation. The catalepsy was replaced by lethargy. The kitten did not react to pressure or to tickling of the paws. When sounds were produced close to its ear, the ear moved, but otherwise, the posture of the kitten remained unchanged. Tickling of nostrils made it move its head, but the kitten remained in the same posture with eyes firmly shut.

The kitten was wrapped in its cloth as usual. At first the kitten was greatly excited and squealed. It was rather more difficult to make the kitten quiet than it was in previous experiments. The excitement was antagonistic to sleep. When finally quieted, which took some time, the result was even more successful than on previous occasions. The kitten was fast asleep. Before going into the sleep-state the same phenomenon of transient catalepsy and resistance was quite marked. The limbs then assumed a relaxed condition. It slept so soundly that stimuli that would have awakened the kitten on previous occasions did not disturb it at all, but simply called forth reflex reactions.

The kitten slept for more than half an hour. It was then rudely awakened by me. The kitten was very sleepy and soon closed its eyes and sank once more into a deep sleep.

Three kittens eight days old. Eyes were open. Their movements were still incoördinate. They resisted, when put upon their backs. The kittens were wrapped in a cloth one by one. At first they struggled violently, but afterwards they became quiet and fell into a deep sleep. The limbs were in a state of relaxation. No manifestation of rigidity or of catalepsy could be observed while passing into or coming out of sleep. The induction of sleep took some time, but a few repetitions made the onset of sleep easier.

The kittens were wrapped in a cloth and their movements were restricted. After a little struggle and spitting they went to sleep. This time no symptoms of catalepsy could be observed. The kittens were probably too young to manifest any of these phenomena, for later the phenomena of catalepsy during the time of going into and coming out of sleep were, relatively speaking, quite marked. Closing the eyes did not play such an important rôle in young kittens as did the condition of limitation of voluntary movements. In this respect young kittens behave somewhat similar to young infants.

Kitten, two and one half weeks old; very lively. It struggled to get free. After three minutes the kitten was put to sleep; it was wrapped in a cloth and slept peacefully. On my attempt to open its eyes there was a little resistance, but not marked. On examination the eyeballs were not found rolled up, but they looked staring and sleepy, and the pupils were contracted. The kitten closed its eyes immediately after and went to sleep again. There was little or no response to external stimulations of sound. In the next room much noise was made by a carpenter hammering with all his force. This was not favorable to sleep, but the kitten was deeply asleep and remained undisturbed. The kitten slept for fifteen minutes and was awakened by me for further experimentation.

The cloth has proved itself an excellent factor in putting the animals to sleep. This may be due to the fact that the movements are well limited without much pressure; the

pressure present is more evenly distributed, hence, also more monotonous, a circumstance which greatly helps in bringing about sleep. The conditions must all coöperate to bring about *monotony*.

An attempt was made to put a kitten to sleep without the cloth. The animal was harder to handle, it took me some ten minutes before the kitten was made quiet. It fell asleep but for a brief period of time, possibly not more than a minute. Then it opened its eyes. Now for that short period the paws were found extended, somewhat resistive to but retentive of impressed movements. The paws trembled visibly. This tremor was due to the incoördination of the motor activity of the kitten.

I observed in my experiments on subjects and patients that *sudden* fright might bring about subwaking states and sometimes even hypnotic and somnambulistic states. Now when tested on kittens similar results were obtained. When the kitten happened to be specially refractory, it was frightened by sudden strong stimulations or by suddenly turning it around and around. To my great surprise I found that the kitten's struggles subsided,—the respiration became lowered and the kitten was asleep. As the experiments gave like results the few described will be sufficient for our purpose.

When one of the kittens was very excited and in a fighting mood, I seized it *suddenly*, kept it down firmly, the animal became very quiet, fell into a passive state and then was fast asleep.

Of three young kittens I seized one after another quite suddenly. The kittens became much excited. One after another was put in a cloth, their limbs wrapped all round and kept down quite firmly, so that they could not move. There was but little opposition and still less fighting. By way of intensifying the effect they were given a couple of good shakings, the little ones became quiet, and fell into a sound sleep. They did not react to sensory stimuli; their paws were slightly resistive at first and then relaxed. Respiration, from being labored and quick, became quiet, uniform, easy and lowered.

These experiments were repeated by me over and over

again and with the same results, showing that the latter were not a matter of accident. In fact I found that when I wanted to put the little kittens to sleep speedily, to frighten them by shaking was the surest way of putting them into a more agreeable mood and thus send them off without delay into a sound sleep.

In the experiments on the kittens we find the phenomena of the subwaking states somewhat more developed than in the guinea-pigs or in the frogs. The cataleptic phenomena are not so pronounced as they are in the frog, but the manifestations of the subwaking states approach more closely the manifestations observed by me in human subjects. The state is more hypnoidal in character, there is present the transient, scarcely perceptible catalepsy which appears for but a moment, giving way immediately either to sleep or to the waking state. Of course, we should not expect to meet with a typical, fully developed suggestibility or somnambulistic state in guinea-pigs or in kittens, considering the fact that even in man, the imbecile, the idiot and the mentally obtuse hardly go into any such state. It requires a mind of a highly organized constitution to get into a state of abnormal suggestibility and of somnambulism with their accompanying manifestations. What, however, we do find is the characteristic instability of the manifestations of the intermediary, subwaking, hypnoidal states, having some of the most general somatic symptoms of hypnosis, such as slight catalepsy, but leading into a passive condition on the intensification of the state. The state in which the animal is plunged under the condition of monotony and limitation is *hypnoidal* leading toward sleep.

Chapter IX

Experiments on Dogs

As we come nearer to the higher animals we find it easier to interpret the phenomena under observation and experimentation. The subwaking states become more defined and sleep is fully recognized at the first moment of its oncome. Thus in dogs we can more easily interpret the different motor activities in relation to their subjective correlatives and accompaniments. Man can so closely put himself into the subjective mood of the dog he knows that he can understand apparently the slightest expression of the animal's wishes and emotions. The artificial selection of the most intelligent and most devoted dogs as well as the constant companionship with the human race could not but affect the canine races and bring the most manifold expression of their emotions, wishes, and desires within the scope of human interpretation. Dogs have the mental touch of man and are described by the poet as dreaming in their sleep:

"Consueta domi catulorum blanda propago
Degere, sæpe levem ex oculis volucremque soporem
Discutere, et corpus de terra corripere instant,
Proinde quasi ignotas facies atque ora tuantur."

Lucretius describes vividly the active dreams of the hound hunting in his sleep:

"Venatumque canis in molli sæpe quiete
Jactant crura tamen sudito, vocesque repente
Mittunt, et crebras reducunt naribus auras,
Ut vestigia si teneant inventa ferarum:
Experge factique sequntur inania sæpe
Cervorum simulacra, fugæ quasi dedita cernant;
Donec discussis redeant erroribus ad se."

Dogs have some imagination, even if they are not poets, and cannot retort man in kind. Dogs, standing higher in the scale of development, lend themselves far better than the rest of lower animals for the study of sleep. As adult dogs are rather difficult to manage for sleep experiments, because

of the excitement in which they are thrown and because of their resistance to being handled by men other than their masters, I selected for my experiments young dogs, especially puppies. I did the same thing in the case of cats for the same reason, as grown-up cats are still more unmanageable than dogs. It is true, as Huebel has pointed out, that if the master of the dog should try his hand, he would no doubt succeed in putting the dog to sleep. Puppies are very docile, they get easily adapted to a new person and do not manifest the individual liking of their master and the abhorrence of strangers as grown-up dogs do. I have no doubt that if a grown-up dog should be put by his master under the conditions of *monotony, limitation and inhibition*, the success would almost be certain in each and every case. In fact, I tried the experiment on an older dog of mine with great success every time I put the dog under the requisite conditions conducive to the oncome of subwaking states and sleep. I shall give an account of these experiments in this research. I find that dogs, like men, easily fall into subwaking states and sleep.

There is also another reason why I chose puppies for my experiments. Puppies, especially very young ones, sleep a good deal and not having the nervous activity and distractions of older dogs are more amenable to the conditions of subwaking states and sleep. In carrying out experimental work it is best to select the material and put it under the most favorable conditions.

We may pass now to the experiments proper. I quote from my notes those experiments which are typical of the rest.

Two puppies of about two months old; very lively, excitable, and barking violently. After some struggle each one was wrapped in a cloth so that even the forepaws did not protrude. At first they were greatly excited by the proceeding and proclaimed their indignation by loud yelping. I took my turn with each one separately. The puppy was held down firmly and given no chance to move its body or to struggle with its paws. I also closed the puppy's eyes with my fingers. The puppy struggled and wriggled under my hand, but I held on tightly. Gradually the puppy ceased

its struggles and became very quiet. Respirations became slow and regular. I gradually released my grip on the dog, when I found that its eyes were firmly closed. The puppy was fast asleep. The same performance was carried out in the case of the other puppy. After five minutes, during which time I held the dog tightly and kept all the extremities in close grip, the puppy passed into a quiet state and fell asleep as the first one did. Respiration was slow and uniform. Both puppies slept peacefully. There was no response to external stimuli. Limbs were in a state of relaxation. In spite of the noise in the neighboring room the puppies kept on sleeping. After twenty minutes one of the puppies woke up, made some show of struggle, but the eyes remained shut and he fell asleep again. I tried to loosen the cloth in which the puppies lay enwrapped. My manipulations did not disturb their sleep The puppies kept on sleeping the sleep of the just. After a sleep of about an hour I had to disturb the repose of the little ones and wake them up, as I had to leave the laboratory, otherwise they might have slept much longer.

The cloth was now uniformly adopted by me in my experiments for the control of the voluntary movements. Unless the little ones were wrapped in the cloth there was great difficulty to restrict their activity. The puppies fought like furies. One of them was specially unmanageable. A few shakings quieted him. The puppy was wrapped in a cloth and after a few minutes went into a deep sleep. It withdrew the paws on irritation or on pinching, but the eyes remained firmly shut. Respiration and pulse were slow.

The puppies were put to sleep under the same conditions. This time they could not sleep soundly, on account of the continuous noise in the next room. They woke up every time, but fell asleep again. They growled in their sleep, evidently reacting to the external noises, but they did not wake up. One of the puppies turned on one side, apparently to make himself more comfortable and kept on sleeping. They were, however, to-day more restless than they were on former occasions. Maybe hunger gnawed at their entrails, maybe it was the noise of the school that the puppies could not stand. After about a quarter of an

hour they woke up and looked like two little surly pups. I gathered them once more up into the folds of my cloth, and gently, but firmly, forced them to sleep again. They went to sleep much more easily with no fighting. When passing into sleep, I tested the forepaws of each of the puppies. As this time the forepaws were quite free, I could observe well their position, change them, and manipulate them. At first the limbs showed some resistance to change of retained position impressed on them, a slight cataleptic state. Then the limbs relaxed and remained in this condition till the end of the experiment. This time the noise in the adjoining room ceased and the youngsters seemed no longer disturbed. I let them sleep for about three quarters of an hour, when I began to tickle them, pinch them slightly, and change the position of the paws. They began to move restlessly and gradually got out of sleep. The eyes opened lazily, and they evidently felt ready to go to sleep again. Before waking up fully there was a slight state of resistance in their forepaws, catalepsy seemed to return again. This slight catalepsy in regard to retained postures and to changes of the position of the extremities lasted a few seconds and disappeared. Thus in getting out of sleep the puppies passed once more through some subwaking state with its accompanying catalepsy.

The puppies were put to sleep again. The conditions of monotony and limitation were the same as before. Forepaws were free, protruding from the cloth. When the puppies sank into sleep, the paws were slightly resistive. The least disturbance brought the puppies out of the passive state. Typical manifestations of subwaking, hypnoidal state were present. Respiration gradually fell, the passive state became intensified, and the puppies fell into a sound sleep. The paws became fully relaxed. The eyelids were firmly shut and at first resisted pulling apart. When the eyelids were separated, the eyeballs were found rolled up; pupils were in state of contraction. When I let go the eyelids, they closed again and remained firmly shut. There was almost no response to external sensory stimulations. The puppies slept half an hour, when I began to waken them slowly, again before full waking a slight cata-

lepsy was observed in the limbs, the puppies passed through the intermediary, hypnoidal state. They looked sleepy when they opened their eyes and kept closing them. They stretched their little paws as after a good sleep and yawned.

One of the puppies was very irritable and surly; it fought like a little fury. It squealed, barked and yelped. After a little jostle in the cloth it fell asleep peacefully. Again a slight catalepsy of the limbs was observed for a brief period of a few seconds, then relaxation set in. The puppy slept very soundly; it did not react to stimuli of medium intensity. Reflexes of forepaws were present and when the stimuli became summated the paws changed position, the body then also tended to change its posture. The eyelids were firmly closed; when opened by force, the eyeballs were found rolled up and the pupils contracted.

The other little puppy was more amenable to treatment,—it did not resist, but seemed to be resigned to its fate. When wrapped in the cloth, it was very good natured. When I put my fingers on its eyelids and had them firmly shut, the puppy remained in the same position without fighting. Respiration was quiet, uniform, lowered. As the puppy sank into sleep the paws were found slightly resistive to bending; they were extended, but soon became relaxed and remained so throughout the sleep state. The puppy slept quite peacefully. Reflexes of forepaws were present. It did not react to slight stimulations, such as tickling or pinching of the skin, or even to pricking of the forepaws. It did not react by shifting the body or by waking up and opening the eyes, it only moved the forepaw that had been stimulated. The eyelids were firmly shut and resisted opening. When opened by force, the eyeballs were found rolled up, so that the whites or the sclera could be well seen partly covered by nictitating membrane. The dog was awakened by summation of slight stimulations.

Three new puppies were very tractable. They fell asleep with the greatest ease imaginable. The puppies were about two and a half weeks old, were quite gentle and showed almost no resistance. The same phenomena were present as in the other dogs; they went to sleep under the

same conditions, their paws for a brief period of a few seconds were extended and slightly resistive. Limbs retained the position given to them. The eyelids were firmly shut and there was resistance to attempts to force them open. When forced open, the eyeballs were rolled up, and the eyelids closed as soon as they were let go. The puppies seemed to possess the power of sleeping indefinitely. Now and then sucking and snapping movements were observed. They slept for more than an hour and would have gone on sleeping had not they been rudely shaken out of their peaceful repose.

The experiments were repeated over again with the same results. As the puppies got older the manifestations of the transient, intermediate state became more pronounced,—catalepsy was more evident on falling asleep. The same held true in the case of waking up. There was a slight stiffness and catalepsy of the paws for a brief period when the puppy emerged from sleep. On falling asleep the puppies did not tumble at once into that state, they opened and shut their eyes, when my fingers were released from pressing their eyelids. They kept on blinking the eyes. The lids came nearer together and finally closed. The same process of blinking was observed on waking; they seemed to wake and fall asleep again, thus being really in the intermediary, hypnoidal state, hovering between waking state and sleep, both on going to and coming out of sleep.

With the repetition of the experiments the little fellows learned to go to sleep with greater and greater ease, manifesting, as time went on, more and more clearly the characteristic symptoms of subwaking and sleep states. After a time there was no need to keep their eyelids closed with my fingers; it was enough to shade their eyes with my hand or with any opaque body and the eyes after a few seconds began gradually to close. A slight tremor of the eyelids was observed as they kept on opening and closing, somewhat similar to what we find in the first stages of hypnosis. Only here it was not really hypnosis, but the hypnoidal state, partaking of hypnosis, waking state and sleep. The puppies did not really go into any hypnosis, but into something bordering closely on the hypnotic state. Instead of going

into the hypnotic state, however, as the fully developed human subject would occasionally do, the puppies went into sleep.

What interested me most in the puppies was the fact of their habituation to the sleep-procedures. They seemed to like the whole procedure and had no objection to my manipulations, so that after a time I even ventured to put them to sleep on the table without wrapping the cloth round their limbs; the little fellows went to sleep as cheerfully and as soundly as before. They lost all fear and lent themselves readily to the operations. It was thus sufficient for me just to put them down on their sides, and it did not matter on which (they would not sleep on their backs), when the puppies, of their own account, almost, went into their customary subwaking and sleep-states.

Those puppies were gone and another puppy, an untrained one of the same litter, had taken their place. This little fellow was about a couple of months old and was a hard nut to crack. He was sturdy, fat and refractory. I had quite a tussle with him. It took me more than half an hour to appease him. He became quiet for a few minutes and seemed to have gone off into a passive condition closely bordering on sleep, but he was soon up and in arms again. Maybe the loud knocking in the adjoining room disturbed the experiments.

I wrapped him all round in the cloth and shutting his eyes firmly with my fingers and holding him down tightly with my hands, I finally succeeded in moderating his ardent temper. The loud barking gradually subsided, and finally degenerated into growling. This growling really added to the monotony of the sensations. The growling then diminished and the little fellow began to breathe more quietly, the heart-beat due to excitement subsided, and the puppy fell asleep. He slept quietly for about ten minutes only and woke up again. His eyes looked sleepy and he yawned for some time.

An attempt was made to put him to sleep under the same conditions of monotony and limitation, but it was difficult to quiet him. He barked and struggled and refused to let himself be controlled. It was decided to let

him go for that day. This condition kept on for several days. The most that could be done with him was to wrap him in the cloth, hold him firmly with the hands, and have his mouth shut.

I confess that at first I almost despaired of ever breaking the youngster into the game. I kept at him, however, and after a long series of trials the little fellow did not meet me any longer with such feelings of opposition. Finally one day after a hard tussle and a few severe shakings I decided to leave him to himself. To my great surprise the puppy became quiet, his eyes became perceptibly narrower, and at last he fell asleep. The sleep was very sound. He did not open his eyes when I changed the position of his paws, nor did he even open his eyes when I tickled the paws or pricked them. The only response to those stimulations was the reflex movement of the paws, drawing them away from the direction of the stimulus. The eyes were firmly shut, and when I attempted to separate the eyelids, the latter resisted quite perceptibly my efforts. When I did open the eyelids, the eyeballs rolled up and the pupil was contracted. The puppy slept for about half an hour. I decided to awaken him and see what he would do and also to observe the stages which he would pass in getting out of the sleep-state. The cloth was unrolled. This awakened him. He opened his eyelids, stretched his forepaws and was going to sleep again; the eyes closed. On testing his forepaws, there was some resistance, though very slight, but it could be noticed on attempting to bend the paw at the joint. The eyes opened and closed; finally they opened fully and the little fellow stretched out his paws and yawned with a good relish as after a delightful sleep. At last then my long efforts were crowned with success. The puppy did fall asleep and in waking was observed to pass through the characteristic stages of hypnoidal states.

The advantageous moment was then seized to push the matter for all it was worth, to again induce sleep under the conditions of monotony and limitation now that the puppy proved so obliging and went off into sleep on its own account. The cloth was wrapped round the puppy's limbs

holding him down firmly. I closed his eyes with my fingers; the puppy, having been just awakened from his deep sleep, felt more gracious and did not kick much, opposed but little and in a few minutes fell into a deep sleep. After sleeping for about a quarter of an hour he was awakened. On awakening for a brief period the presence of the intermediary, subwaking, hypnoidal state was observed. I immediately proceeded to put him to sleep again, giving him no respite and plunging him rapidly in succession from waking into sleep and then again from sleep into waking states. This process was kept up a few times until it was quite certain that the little fellow was under control. The puppy got thus habituated to manipulations as well as to the rapid transitions from waking to sleeping and back again. Every time he was brought out of sleep the puppy was very quiet and did not resist my efforts to put him to sleep again. At first I did not dare to observe closely and especially to experiment on the first stages of going into sleep, lest I might disturb the puppy and thus break the charm, as I was anxious that he should first of all be habituated to the process and to the sleep-states under the conditions of monotony and limitation and should cease to show resistance. After a number of experiments the puppy became tractable and thenceforth the experiments could be carried on without any further protests and rows on his part.

From now on the experiments proceeded in peace. When occasionally the little fellow became obstreperous, a few shakings brought him to his senses.

After wrapping the puppy in the cloth, and holding him firmly with both hands, I closed his eyes with my fingers. After a few seconds the puppy fell asleep. The eyelids were firmly closed. When an attempt was made to open them, they resisted; when the eyelids were separated forcibly, the eyeballs were found rolled up. There was contraction of the pupils and when darkened with the palm of my hand, the reaction was very sluggish. When the conjunctiva was touched with my fingers, there was a slight reaction of closing the eyelids and slight shifting of head and body, but the puppy remained asleep. He slept

for about half an hour and was awakened for further experimentation. On awakening, the puppy passed as usual through the transient subwaking state characterized by slight catalepsy of the extremities.

The puppy was put to sleep again with the cloth about his extremities; the forepaws were more or less loosened for observation and experimentation. The head was left protruded out of the cloth so as to observe the changes. This condition was always observed in my experiments on sleep, only in some cases the head was kept a little covered so as to keep out the light. In this case I had the head fully uncovered. My fingers were kept on the puppy's eyelids, but I removed them in a few seconds. The eyelids were found partly closed and I observed a peculiar tremor of the eyelids similar to that found in human subjects before falling into the hypnotic state. The eyes of the puppy were shaded with the palm of the hand. Gradually the eyelids closed tremulously. It could be distinctly seen how they opened partly, and then closed again. After the eyelids became fully shut, a peculiar phenomenon strikingly analogous to one manifested in hypnotic subjects, was observed; the puppy seemed to try to open the eyes but could not do it. He tried evidently quite hard to raise the eyelids, but only succeeded in raising a part of the lids, thus exposing a slit of the sclera; the eyeballs in this ineffectual effort of the puppy to open its eyes were seen to be rolled up. The eyelids closed again. The efforts on the part of the puppy to open its eyes were repeated a few times and each time the attempts were in vain. The eyelids then closed and remained so. This is so striking and so similar to what is observed in the hypnotic subjects that one is almost tempted to describe this condition as hypnosis. At any rate one is justified in saying that we observe here a *phenomenon which is strikingly analogous to the hypnoidal state*. In going, then, into the sleep-state the puppy passed through a state which is evidently on the borderland of sleep and what in the human subject is described as hypnoidal. This borderland state forming an intermediary state between waking on the one hand, hypnosis or sleep on the other, is just what characterizes the subwaking, hypnoidal

state. There seemed little doubt that in going into sleep the puppy did pass through hypnoidal states.

Another fact that may be of interest in the sleep of this puppy, as well as of the other puppies under observation, was the shivering in going to sleep. The extremities trembled when raised and a transient state of resistance and catalepsy was often observed. This catalepsy was specially pronounced when the forepaw or any other of the extremities was extended and a little manipulated. It seems as if we give here a suggestion to the puppy, as is the case with the state of abnormal suggestibility in the human subject. I may add that these manifestations of the hypnoidal state were not so marked on awakening.

After control was gained over the puppy he could be handled safely. It was thought it might be well for the sake of the experiment to irritate the dog a little and see what would be the result. He was forcibly pressed and choked very slowly so as to avoid the sudden onset of excitement. He yelped, but it seemed that the habit of going to sleep was even stronger than the excitement. In spite of all the irritation the puppy soon became quiet and when his hind limbs were wrapped around, he soon was disposed to fall asleep. With my fingers I just covered his eyelids, but did not press on them. It was just the merest suggestion of pressure on the eyes, but the little fellow went into a sound sleep. Before falling asleep I observed the usual blinking of the eyes, the opening and closing of the eyelids and twitching of the orbicularis palpebrarum as well as the rise and fall of the eyelids until the eye became completely closed. On attempting to open the eyelids there was great difficulty in separating them. On examination the eyeball was found to be rolled up, the pupil contracted and not reacting to light. The conjunctiva was found almost insensitive. The dog responded to stimulations by reflexes of the forelimbs and on stronger stimulations by movements also of the hind limbs, but he did not wake up. At first the limbs were slightly resistive, especially when I manipulated them, pressing and kneading the muscles of the upper front leg. The cataleptic state of the extremities was, as usual, only transient and the limbs remained

during the whole state of sleep in a condition of relaxation. The same state, though slighter, was as usually, also present when the dog was aroused from his sleep by a summation of stimuli.

The sleep-experiments were carried out on this formerly refractory puppy with great ease. In fact, the facility with which sleep was induced far exceeded the experiments performed on any of the animals handled before. It could only be compared to the ease with which a subject on repetition of hypnotization goes into hypnosis. Still it is not possible to regard the sleep of the puppy as hypnosis. There is no suggestibility present, nor that characteristic *psychophysiological plasticity of associations and dissociations during or after hypnosis.* The state in which the puppy falls is nothing else than normal sleep. Only in passing into that condition *there are present manifestations which recall the hypnotic state.* The reason is very simple, the puppy is passing through a state which is intermediary in character between waking state and sleep. This intermediary state is hypnoidal in nature and has some manifestations which are analogous to hypnosis in the higher and more developed mental states of man. In the dog we have the foreshadowing of what is afterwards fully found in man alone. *The hypnoidal state precedes and succeeds sleep.*

As I continued my sleep-experiments on the puppy, it became easier and easier to put the little one to sleep; so much so that after a time I could put the puppy into sleep, first passing through all the stages observed, though the cloth, that magic for the induction of sleep, was no longer used. I put the puppy on the table, just kept him quiet by patting him a little, and pretty soon off the little fellow went into the land of Nod.

The puppy was put on the table, then laid down on his side—he did not resist, he kept as quiet as a little lamb. His eyes were shaded with a screen and the little fellow marched off into sleep. To produce sleep in the puppy after a few weeks' training was just child's play. The contrast to his previous unmanageable condition was great indeed. It was now possible with the greatest ease to have

him pass from sleep to waking and from waking to sleep. The contrast here was also very surprising, the puppy played, ran around, barked violently and in a few moments he was fast asleep with limbs relaxed and immovable, with eyes firmly closed, eyeballs rolled up, pupils contracted, conjunctiva anæsthetic, and all the sense-organs dulled and stupefied, as if by a hypnotic or anæsthetic. In a few moments more the puppy was up again, gave a yawn or two and was as restless and playful as ever. The transition from one state into the other was so rapid that it was almost marvellous.

The puppy was found very restless, barking and jumping, but as soon as he was put on the table, his limbs were kept quiet for a few moments, his eyes shaded; his eyelids began to blink and the muscles around the eyes to twitch, and the fellow began to shiver, not from fear, as the heart-beat was not accelerated, but slower, and the respiration was tranquil and lowered. The shivering was one of the phenomena observed in puppies, when on their way into sleep. What was specially interesting in the series of sleep-experiments was not only the significant fact that the puppy under the conditions of monotony and limitations was going off into sleep without resistance and delay, but that before going to sleep, when the eyes were about to begin to blink, and the eye-muscles to twitch, the *little fellow raised his eyes to me and looked at me and then, as if satisfied that everything was all right, off he went into his sleep contentedly.* This state is often observed in the hypnotic subject.

It seemed to me worth while to test whether the personality of the experimenter had any influence. When putting the puppy to sleep, I called Dr. Cannon to see it to test the phenomena of the subwaking hypnoidal state. To my great surprise I found that I could not succeed with the puppy as well. There was some difficulty in putting him to sleep, although there was not really active resistance. It took me some time before I could put the puppy to sleep and then test for the hypnoidal state and show it to Dr. Cannon. *There seems then to be a true personality-element present in the experiments.*

I then left the puppy for about a week. I wanted to see whether it would make any difference in the ease of putting him into the sleeping condition. After more than a week, I found that he did not submit so cheerfully as before. It took me fully ten minutes to put him in a state of sleep. Finally he did go into a sleeping condition with all the symptoms characteristic of the subwaking and sleeping state. In about a quarter of an hour he woke up, but soon fell asleep again and slept for another half hour, after which he was awakened. He seemed sleepy and looked ready to go to sleep again, which he really did after I had kept his limbs and body quiet for a few seconds and the eyes shaded. Thus the habit was quickly re-established.

To bring the personality-coefficient, so to say, more to the foreground, I decided that the dog should be put to sleep under the same conditions of monotony and limitation, not by me, but by another person. I asked Mrs. S. to lend me a hand in the present experiments and see what she could do with the puppy in putting it to sleep. The puppy was kept quiet on the table without being put into the cloth as I had been lately conducting my experiments; but the result was not successful. Mrs S. then resorted to the old conditions, namely to the cloth. The puppy went to sleep, but after some considerable trouble, though I must say he did not show any fight as I should have expected. It was then easy enough to put him to sleep without any cloth, though Mrs. S. could not accomplish it as easily as I could. *There is then present a personality-coefficient* in putting the puppy to sleep, but the coefficient is very slight in the puppy at least. *The conditions of hypnoidal states and sleep, namely monotony and limitation, are the most important.* For Mrs. S. could put the puppy to sleep; it was only a matter of time. Monotony, limitation and inhibition may thus be regarded as the conditions under which we can induce in the dog sub-waking hypnoidal states and sleep.

I may add that I also carried out similar experiments on a dog of six months old. As the dog was used to me I had no difficulty in inducing sleep. I made him keep quiet and then closed his eyes firmly. He went to sleep. When I tried to open his eyes, they resisted. When I

opened them, I found the eyeballs rolled up, nictitating membrane over part of sclera, and pupils were contracted. There were present the same manifestations of hypnoidal states, the slight catalepsy on falling asleep and a similar, though somewhat slighter catalepsy on awakening. There was little difficulty in putting the dog to sleep. With the repetition of the experiments it was easier to put him into hypnoidal states and sleep under the conditions of monotony, limitations of voluntary movements and inhibition. The dog was very lively otherwise, but when put under the conditions of monotony and limitation of voluntary activity, he sank into a passive state and then into a state of sleep.

We see, then, that dogs are subject to the same condition of sleep-states as is the case with the other animals experimented upon. In fact the experiments on dogs bring out the fact that the conditions requisite to induce hypnoidal states in men also hold good in the case of dogs. The hypnoidal states, both on falling into, as well as rising from sleep, are far more pronounced in the dog than in the lower animals experimented upon; the states themselves come up far more closely to similar states observed in men under the same conditions of monotony, limitations and inhibition than they do in lower animals, such as the frog, the guinea-pig or the cat.

Phylogenetically regarded the hypnoidal is the primitive "rest-state" out of which sleep and hypnosis have become differentiated. The lower the animal the more insecure, the more instable are its "rest-states," The animal must be on the alert in its rest, and "sleep", if at all, with its eyes open, so to say. It must be quick to wake and run from danger or if it cannot get away, it must "freeze and feign death"; in other words it must be able for the sake of protection to fall into a state of catalepsy. Hence the rest-states must partake of waking, sleep and hypnosis, that is, must be essentially hypnoidal in character.

The experiments on dogs are more instructive than the ones carried out on the other animals, because they clearly bring out the general principle of monotony and limitation in the causation of sleep. *Diminution in the variability* of the volume of sensory impressions *brings about the state of sleep.*

Chapter X

Experiments on Children

THE experiments on animals were followed by experiments on children. The subjects were of different ages ranging from infants a few days old, to children twelve and thirteen years of age.

It is well known that children usually fall asleep more easily than adults; they sleep longer and also more soundly. This is specially the case with young children and particularly with infants. We know that an infant passes most of its time in sleep, when it does not eat. We should expect therefore that the material would readily lend itself to our present purpose of experimentation, — to the induction of sleep-states. Now as a matter of fact, I find that in a number of my cases dealing with children it is no difficult task to put them to sleep, or to induce some form of subwaking state, hypnoidal or other closely allied to it. The child easily falls into a subwaking hypnoidal state which may either pass into hypnosis or into sleep. When trying to put children to sleep I have often obtained a hypnotic condition and on the other hand when attempting to put my little patients into a hypnotic state I have only succeeded in putting them to sleep. Before going, however, into either the hypnotic or sleep-state, I observed by close examination the presence of the hypnoidal state induced under the conditions of monotony and limitation of voluntary movements.

Since limitation of the voluntary activity, limitation of the field of consciousness and inhibition all help to a greater monotony, we may characterize the whole set of conditions requisite for the induction of sleep as the conditions of *monotony*. In children and especially in infants voluntary activity and the field of consciousness are undeveloped and limited, we should expect that the child would form a far better soil than the adult for the induction of the intermediary sub-waking states and sleep. This is precisely what we find to be the case.

Moreover, the mind of the child, and more particularly of the infant, specially depends on muscular activity and on the wealth of incoming sensory impressions. That is why the child and the infant take such delight in motor activity,—in tasting, testing, and handling things. If now the motor activity is limited and the main source of sensory impressions, such as sight, is restricted, and if the environment is kept in a state of monotony, such as darkness and lack of auditory stimulations, or monotony is brought about by a continuous noise and buzzing of some instruments producing a uniform noise, the child, on account of the poverty of its inner mental life, easily falls into a subwaking hypnoidal state and then into sleep.

This ease of induction of sleep is furthered by the comparatively small amount of variability of conscious activity present in the child — the variability of mental content being an important factor in keeping up the freshness, continuity and qualitative intensity of consciousness. Now as the child depends entirely for the variability of its consciousness on muscular activity and external impressions, we can well realize that when those sources become limited and monotonous, the child falls under the influence of all the important conditions requisite for the induction of sleep. The child in short, has no inner wealth of mental life to fall upon; it has little, if any inner resources; that is why it falls an easy prey to sleep and hypnosis, when the external resources lose their variability, become uniform and monotonous.

It may be well, however, to point out the fact that the conditions of sleep are somewhat different in the case of infants of a few days or of but a few weeks old. Young infants sleep most of the time. The waking periods are brief and alternate with long periods of sleep. Really the infant's state is one of sleep and he only wakes to eat. We may characterize the infant's waking states as *feeding* periods. The perceptual world may be regarded as practically non-existent for the infant—ego and non-ego are absent. The external world is in a chaotic state with no interests, even instinctive ones, as yet present. The sensory organs are as yet undeveloped and the sensory elements are all incoördinated and unrelated. Even the raw ma-

terial going to make up the future world of the individual is still in an extremely imperfect state. In short, the material presented by the undeveloped sense-organs is chaotic, undifferentiated and is at its *minimum.* There is really no external world for the infant and whatever sensory impressions are present lack meaning and interest.

But if the sense-material coming from the sense-organs which is to build up the infinite wealth of the external world is still undeveloped and lacks all significance, it is quite different with the sensations coming from the internal organs, from the viscera. The visceral, organic sensations stand out in the foreground of what may be regarded as the infant's consciousness. Visceral, sensory material forms the main substance of the infant's universe. *Cœnæsthesis plays the predominant, if not the only rôle, in the life of the newborn.* We can fully realize the importance and significance of cœnæsthetic sensations in the case of the infant, because the processes of growth and nutritive functions are all engrossing. The newborn is a vegetative being; it is all belly, stomach; it is a little glutton, it has to grow and that very rapidly; it lives for that purpose — it eats and sleeps. The waking periods are sparse, short and far between, the infant wakes to eat, and when filled to the point of regurgitation, it sleeps.

In this respect it may be well to observe the characteristic motor reactions of the newborn; the sucking movements are the only ones that are well coördinated, responding regularly to external impressions. Thus in my experiments I have long ago described the interesting fact that in his early life the newborn responds to external stimulations with sucking movements. If the infant, for instance, is put to the breast and has his fill and the sucking movements stop, they will again be reinstated by any stimulations of his sense-organs. Make noise close to the infant's ears or throw some rays of light on his eyes, or tickle him, or cause him pain, or tug at the nipple, and the infant responds with sucking movements. In other words, all reactions of the newborn are coördinated and essentially adapted to nutritive purposes. *Nutrition and its psychic correlative, cœnæsthesis, form the essence of the infant's early life.*

It is therefore clear that the conditions of monotony of external sensations and of limitations of voluntary activity, an activity really absent, as well as limitation of the field of consciousness, can hardly be of any import in the young infant. The gnawing of hunger, intestinal discomfort and pain play the only important rôle. In the early life of the baby visceral activity and its concomitant cœnæsthesis possess the greatest amount and intensity of qualitative variability that keep up the limited consciousness of the waking state. When the child is hungry, it is fidgety, cries and is awake; when hunger is appeased, the waking state lapses and the baby falls asleep. The waking state is a brief passing phase in the feeding of the baby, a feeding phase which begins and terminates in sleep.

If now we take all that into consideration, we should not expect to meet with clearly defined subwaking states and sleep under the conditions of monotony and limitation in the case of the newborn as we find it to be the case in the lower animals a couple of weeks old, or as we find it in the fully developed man. The young of the lower animals have a shorter training period and have a far larger amount of ready made and easily developed instincts or psychomotor reactions than the baby. When the newborn is put under the conditions of monotony and limitation of the incoming external impressions and under restriction of voluntary activity which does not as yet exist in him, the results are necesarily unsatisfactory. If the infant is full to the point of regurgitation, it goes to sleep, and if it is hungry the closing of the eyes and the attempts to hold it down by force are often quite ineffectual. The baby keeps on crying to the great discomfiture of the experimenter. The easiest and possibly the best way to bring about monotony in the newborn is to soothe the youngster's bowels. If again the young baby has indigestion, stomach-ache and cramps, closure of the eyes and holding the little one quiet without permitting him to kick will hardly do. In such cases the best way is to bring about *monotony and limitation of cœnæsthesis*. Giving the baby to suckle may appease temporarily the active peristalsis of the intestines and the little fellow may pass into the land of Nod; or we may press

uniformly on the abdomen and keep on rocking the little body at a uniform rate. By thus effecting a *monotony and limitation of the bowel-consciousness and intestinal activity* we can bring about a state of sleep. Still, even in the very young infants I succeeded, when the little one happened to be specially well disposed, in putting it to sleep by keeping it very quiet and closing its eyes. In one case I succeeded in putting to sleep a refractory infant under the usual conditions of monotony and limitation by closure of eyes and holding down the baby's extremities from being too active. Usually, however, in very young babies I somewhat modified my proceedings of monotony and limitation by addressing myself to the baby's *inner intestinal consciousness*. In older babies and young children of over a year, I did not vary my usual proceedings in the induction of sleep under the conditions of monotony, limitation of voluntary activity and of the field of consciousness.

We may now pass to the experiments. I shall follow here the same course as in my account of the experimental work performed on the lower animals, I shall not burden the reader with unnecessary details, but shall give a few cases of experiments, typical of the rest.

Boy of twelve days; he was quiet; he looked into empty space, seemed not to be specially hungry nor ill disposed. I covered his eyes with my hand and restrained the movements of his limbs. He wriggled a little under the restraint, but soon became very quiet. When after a minute's time I removed my hand from his eyes, the eyelids remained shut. Breathing was quiet and uniform. I tried to pull apart the eyelids and found them resistive. When I forcibly separated his eyelids, I found the eyeballs rolled up, pupils contracted. He slept this way for a few minutes. When he awoke I made a second attempt to put him to sleep, but this time with no success. The little fellow wriggled and squirmed. The eyes rolled incoördinately and looked vacantly into space. Closure of his eyes was of no avail. I then modified the procedure, patted his back, soothed his belly, and shut out the light from his vacantly blinking eyes. Gradually the little man relaxed his eyelids, began to work them and fell asleep. This

time he slept for about a quarter of an hour. I then awakened him by summation of slight stimulations. During the course of awakening, I observed a short state of resistance in the extremities. He was again put to sleep in the same way and when going into sleep the same state of resistance and catalepsy of the extremities was observed. The sleeping state was very deep, inasmuch as the little fellow was not disturbed by any sensory stimulations and only a good shaking brought him out of this deep state of sleep.

A girl of ten days; very quiet. I restrained her motor exuberance and with the other hand I closed her eyes; she at first resisted and cried, but after a couple of minutes she fell asleep. Respiration, quiet and equable. Eyelids resisted attempts to pull them apart. Eyeballs were found rolled up; pupils were contracted. I made another attempt and found it somewhat more difficult, but the child became quiet, had eyes closed for a couple of minutes and opened them again. The third time the success was even less marked. I then once more resorted to my method of back patting, bowel-soothing, by rubbing and patting the abdomen and monotonous rocking movements. The little girl was evidently pacified and went to sleep. When falling asleep, there was a short stage of catalepsy, the raised hand remained for a short period, a few seconds, in the position given to it, then a state of relaxation set in. This relaxation of the limbs did not persist during sleep, but now and then I could succeed in giving a cataleptic attitude to the arm. Soon the arm dropped and then again it was possible to put it into a cataleptic condition. The sleep was evidently not stable; the little girl apparently kept on oscillating between sleep and waking state. It seems to me, however, that it is more probable that the sleep-state in young infants is *not differentiated* as it is in the case of adults or of older children. The phenomena of sleep also present some characteristics of hypnosis and hypnoidal states, possibly, because the states of hypnosis proper are as yet embryonic — hypnotic or hypnoidal manifestations thus appearing in sleep.

Boy of ten days. I had great difficulty in putting him to sleep by the ordinary methods of closure and restriction of muscular activity. I had to resort to my modi-

fied method — patting, tapping and rocking until he fell asleep. In passing into sleep there was a slight state of rigidity and catalepsy of the limbs which soon changed to one of relaxation, but in the middle of sleep, when tested again for catalepsy, he developed one but it passed off and could not be again noticed until several minutes later I tested during that interval; limbs were found to be in a state of relaxation.

The interesting fact about the infant's sleep is that once asleep the infant is not so easily roused. This fact is sometimes very striking, especially, when the child has had its fill, and still more, when it has had its bath. To arouse the infant from its sleep is then pretty difficult and I have worked hard over the baby before I could disturb its peaceful repose. Some of the infants I have occasionally found so deeply immersed in sleep that even shaking could not arouse them. I had to give up all attempts to bring them out of the state of Nirvana and had to wait for a more favorable occasion.

Girl seven days old. Ordinary ways of putting to sleep did not work here and I had to resort to the rocking, patting and tapping before my efforts were crowned with success. The girl fell asleep in a state of rigidity and catalepsy soon replaced by relaxation. The eyeballs were rolled up, but the child was restless. I put her again under the same conditions of monotony and this time she slept more peacefully — I had in fact, some difficulty in waking her. The state of awakening was characterized by a greater resistance of the limbs than the sleep-state. Still, even in her sleep I could now and then discover a cataleptic state. *The sleep of the infant appears to have a mixed symptomatology of sleep and hypnosis.* The characteristic manifestations of sleep, however, predominate.

Boy two weeks old. I left him in the same position, but only shut his eyes forcibly with my fingers for not more than twenty seconds. He opened the right eye after thirty seconds, and the left eye remained closed for a minute and a half. This incoördination is observed in young infants. He did not fall asleep, however, before I tried the monotonous rocking, the baby being placed with his

belly downwards resting on the palms of my hands thus causing a uniform pressure. In sleep I observed a cataleptiform state. Hands remained in the attitude given to them. This lasted for but a few seconds.

I can induce sleep in the boy by the following procedure which is really another modification of the conditions of monotony and limitation of muscular activity. I either rock him for a time, while sitting quietly in the chair or take him in my hands and walk around with him, which also induces monotonous rocking movements. During all this time I sing to him some monotonous ditty. Sleep is more rapid in its onset, when the belly is pressed with my hands uniformly. The boy's eyes begin to close, first becoming as if fixed, hazy and vacant. He closes the eyelids, opening and closing them alternately, the eye is fixed in the same direction. The eyelids then close, then half open. The slit of the eye becomes narrower and narrower and finally the eyelids close and open no more; the little fellow is sound asleep. If his position is left unchanged, he remains asleep for a very long time. If, however, he is put in the crib, he wakes in about five or ten minutes.

When the boy is six weeks old, I can induce in him sleep, by simply closing his eyelids and singing to him some monotonous ditty. When the boy is not tired and has had a good sleep before, he falls into a peculiar state. *He is apparently not asleep and still he is unable to open his eyes for a couple of minutes and even more.* When he is fatigued, he immediately goes into a deep sleep.

Boy three months old. Can easily be put to sleep by monotonous stimulations usually of the character described. When asleep, he is slightly cataleptic; the lethargic condition, however, predominates. The limbs remain for some time in the position given to them, although the position is a very uncomfortable one. When he rapidly falls into deep sleep, he often retains the limbs, especially the arms in the *same position*, however awkward, in which they were put at the moment when he fell asleep.

In following the course of the child's sleep-states, I find that between the sleeping and waking states there is frequently, in fact there is almost always present, an inter-

mediary period of semi-waking, semi-sleeping state, or what is found by me to be present in lower animals as well as in man, when falling asleep, namely a subwaking, intermediary, hypnoidal state. This state is of long duration, sometimes lasting several minutes. It begins with the contraction of the levator palpebrarum, with twitching and trembling of the eyelids, the eyes gazing vacantly into space. The eyelids open and close unequally, the eyeballs begin to turn up, the pupil is contracted. If in this state, he is addressed in a caressing way with which he is familiar and which in the full waking state he greets with a smile and a kick, he now *starts violently*, the limbs going up, and he utters his peculiar cry of *great fright*. Often, however, when he is in this intermediary hypnoidal condition instead of passing back to the waking state, he falls into a deep sleep. When passing from this hypnoidal state into sleep, he is often seen to smile and almost laugh, occasionally he makes movements of mastication, sometimes gives a start and a cry, and keeps on sleeping. It is a form of hypnagogic or even dream-hallucinations.

As to the states which form the transition stages between sleep and full awakening or the intermediary states in his getting out of sleep, I have often had the opportunity to observe the following spontaneous manifestations. When the soundly sleeping child is awakened by a noise, he throws up his arms, as if in fright, half opens his eyes and falls immediately asleep again. The fingers of the hands remain *open and extended, as if in a cataleptic state.* When I try to close them, I find them *resisting* and after a time they close gradually. The rest of the body is in a state of relaxation. I observed it accidentally as the result of an unintended noise, but I since tried to reproduce some similar sudden noises and obtained like results.

When the boy was three and a half months old, I put him to sleep under the usual conditions of monotony and limitations of muscular activity. He fell asleep, his right hand and fingers remaining in cataleptic state, he kept them in the same position when he went to sleep. The fingers were outstretched and the arm raised. I tried to bend one of the fingers, there was no resistance, but curiously enough

as we find it to be in hypnosis, *the finger soon returned to its former position.* The arm remained in the raised position for about three and a half minutes and then gradually dropped. The child remained quiet in this position of fully relaxed limbs for about four minutes then suddenly gave a subdued cry of distress, probably due to some dream; the arms went suddenly up, especially the left one which remained in *a raised position with fingers tightly closed.* This lasted for about two minutes and a half. I tried to open one of the fingers, and met with no resistance. I kept the finger in state of extension for about a minute: as soon as I let the finger go, it *returned to its original bent position.* I soon observed him roll his eyeballs under the still tightly shut eyelids; then he opened his eyes, smiled at me and fell asleep again. As he was falling asleep with eyelids closed I could see the eyeballs roll, while the face retained its smile for a couple of minutes longer, as if smiling in his sleep at me. The state is evidently an almost fully developed subwaking, hypnoidal phase, bordering on waking, hypnosis and sleep. In fact we observe here already the *suggestibility of hypnosis which is on the way to become differentiated from sleep and hypnoidal state.*

We may now give a rapid review of experiments carried out on older children ranging from the age of four to the age of fourteen. The hypnoidal states become more marked, the hypnotic and even somnambulistic states come to the foreground, and we find that when sleep is induced we often get mixed manifestations of a subconscious order. Mixed, however, and still ill-defined as they are, when compared with the adult states, both the subconscious and sleep states are induced under similar conditions of monotony and limitation of voluntary movements. In trying to induce sleep we may get a subconscious hypnotic state and on the other hand in making an attempt to bring about a hypnotic state, we may get a state of sleep. A good deal depends on the fact whether or not we have eliminated the other conditions requisite for hypnosis, but not for sleep. The indispensable conditions, however, both for hypnosis and sleep are monotony and limitation of voluntary activity. These conditions are all the more indispensable as we have demonstrated

from our experiments that in order to reach either hypnosis or sleep the intermediary, subwaking, hypnoidal state must first be passed through. This intermediary state between waking on the one hand and sleep and hypnosis on the other, can only be induced under the conditions of monotony and limitation of voluntary activity.

A boy of four was put in a dark room; the metronome was set going, beating slow measure. The child was told to lie down on a lounge, stretch out his hands and legs and keep perfectly quiet. His eyes were then shut. After a few minutes his respiration became lowered and regular. He ceased to reply when talked to. At first his arm showed some slight rigidity, but soon after, the arm fell into a state of relaxation. He was not in a hypnotic state as he did not answer any questions and did not take any suggestions. When after a quarter of an hour he was awakened, he did not remember anything about talking to him, nor could we obtain it of him by any methods reaching the subconscious. He was really asleep and did not perceive anything during that period. These experiments were repeated a number of times with the same results. I observed that unlike hypnosis which can be induced in rapid succession, one state not differing very much from the other, in this particular case as the induction of the state was repeated, it was more difficult to bring it about, the state became lighter and lighter and the child was brought out of it by talking to him.

Boy of seven. I put him in a darkened room. My electric battery was set going. I told him to keep quiet and shut his eyes. After a few minutes he began to yawn, I told him to stop. He stopped and I soon observed that his little hand clutched mine convulsively, I tried the arm, raised it; it remained in the same position. I then challenged him to open his eyes. He could not do it. I let him alone in a very passive condition; respiration regular and quiet. When after ten minutes I came to him again, I called him by name; he did not answer. When I began to talk to him, he woke up. During the ten minutes he passed into sleep. This transition from hypnosis into sleep was effected through the intermediacy of the hypnoidal

state which forms the borderland of the waking and sleeping states. The general conditions of monotony and limitation of voluntary activity that favor hypnosis also favor sleep.

Boy nine years of age. I put him into a chair, told him to be quiet and then closed his eyes. He was passive, answered my questions; could open his eyes when challenged. When, however, left alone with his eyes shut and his limbs relaxed, he was found to be fast asleep. He did not answer any questions, did not take any suggestions, did not react to stimulations of medium intensity. When spoken to sharply, he woke up. Both before and after the sleep-state there was a short period when the passivity was quite marked and some resistance as well as disposition to leave the limb where it was placed, although he changed the position of the limb when challenged. In passing then into sleep as well as out of it he passed through the intermediate hypnoidal state.

Girl of thirteen. When put under the conditions of monotony and limitation of voluntary activity, she fell from the transient hypnoidal state into hypnosis and thence into deep somnambulism. After an hour, when left to the monotonous state of her somnambulistic consciousness, she passed into typical sleep, as she ceased to answer questions and woke up when the questions and suggestions were given to her in the usual insistent way. From somnambulism she passed into sleep. On other occasions, when closely watched, it was observed that this transition was effected through the intermediary hypnoidal state. The girl passed from the waking state into hypnosis and somnambulism and then again back into the hypnoidal state and then fell into sleep.

Boy aged thirteen. I put him into a quiet state. Metronome was beating slowly. Voluntary movements of the boy were restricted. The boy was then told to close his eyes. I put my fingers over them and kept them shut for a few minutes. When I raised my hand, I found that his eyes remained closed. His arm, when raised remained in the same position. When his arm was bent, he could not extend it, but when after a few minutes I began to talk to him, he woke up. He was evidently in the hypnoidal state

on the way to hypnosis or to sleep. On another occasion he actually fell into hypnosis not being able to move his eyelids or his arms and even took various suggestions. After a few minutes he ceased to be in communication with me and when suggestions were given to him as they had been given to him before, he did not take them, but woke up when loudly spoken to. In other words he fell asleep, and the loud voice disturbed his sleep.

Boy of fourteen; he had difficulty in going to sleep under the conditions of monotony and limitation, but when these conditions were long continued, he finally went into the hypnoidal state. As I feared to disturb him by too much questioning I left him without change to his monotonous environment. After about a quarter of an hour he was fast asleep, snoring in the chair.

Thus we find that in infants and children, as in the lower animals, sleep, hypnosis, and hypnoidal states are intimately related, sleep presenting complex manifestations of subconscious states which become fully developed in the adult.

Chapter XI

Motor Reactions and the Nature of Sleep

BEFORE we conclude the account of the experiments it may be of interest to make a brief statement of a statistical inquiry in regard to our mode of going to sleep. It is usually supposed that the course and mode of our activities are due to voluntary decisions, that they are irregular, changeable with mood and caprice as our whimsical will is. We are free agents and anything we decide to do we can do in any old way; we do it just as we please and it does not matter to us what the course and arrangement be, provided the will wills it so. As a matter of fact we are far more creatures of habit and instinct than of reason and will. This holds especially true of our fundamental reactions, such as the induction of sleep. If we ask the ordinary person on which side he goes to sleep or on which side he falls asleep most comfortably, the question puzzles him at first. At the first blush it seems to him he can go to sleep on either side; it does not matter. When the question is repeated to him and made clear and he begins to think about it, he soon finds out that he has a definite way of going to sleep. Should he try to go to sleep in a somewhat different manner, he would find it very difficult to fall asleep. We have definite ways of reactions which are due either to habit or to the structural arrangement and mode of function of our organism.

Manaceine in studying motor reactions in sleep has found that right-handed people react in their sleep with the left hand, while left-handed react with their right hand. I have similarly experimented on human subjects and could not confirm Manaceine's results. In my experiments on infants I found that in early infancy the reactions in sleep differ but little from that of waking state. The reactions are *undifferentiated*, but I found that later on in the course

of the child's development, the motor reactions mostly conform to Pflüger's laws of reflex action.[1] To quote from my notes:

Boy two weeks old; sound asleep. I tickled his left nostril: bilateral reaction, both hands are thrown up at once. When the tickling is more intense or more persistent and prolonged, motor reactions in both legs are induced. The same holds true in the case of the tickling of the right nostril, the reactions are bilateral and become more diffused bilaterally, if the stimulus is more prolonged or more intense.

The baby reacted in the same way in the waking state, so that there was no difference in the reactions of the two states.

When the baby is fast asleep, I tickle the right temple, the response is a slight reaction with the left hand. This is really accidental. On other similar occasions the reaction is of the right hand and sometimes the reaction is of both hands and also of both legs, according to the intensity or to the cumulative effect of the stimulation.

I invariably found that a slight stimulation given the first time produced a reaction, while a second and third stimulation of the same intensity often produces *no* result.

(1) The following are Pfluger's laws of reflex action.

(I) Law of unilateral reflexes.

If peripheral stimulations cause contraction in only half of the body, the contraction always occurs on the same side as the stimulus, and in general those muscles contract whose nerves arise from that segment of the cord, to which the irritated sensory nerve belongs.

(II) Law of reflex symmetry.

If the effects of stimulating a sensory nerve upon one side extend to the other side, only such motor fibres are called into activity which correspond with those which are already excited on the stimulated side.

(III) Law of unequal contraction on the two sides.

If the contraction is unequal on the two sides, the stronger reflex is always on the side of stimulation.

(IV) Law of reflex irradiation.

(1) When stimulation of a cerebral nerve causes reflex contraction, the motor nerve concerned is invariably either in the same level as the sensory nerve, or it is further downward toward the *medulla oblongata*. (2) When stimulation of a spinal nerve causes reflex contraction beyond its own segment, irradiation always takes place toward the *medulla oblongata*.

(V) The law of three locations of reflex contractions.

Upon stimulation of a sensory nerve, reflexes can occur in only three parts of the body. These are:

(a) at the level of the stimulated nerve.

(b) in parts innervated from the medulla oblongata.

(c) in the whole body.

Boy six weeks old. Tickling of the left ear excites at first movements in the head, in the trunk and then in both hands; when the stimulation is continued, the whole body becomes involved in the reaction, then the left hand is raised. The same holds true in the case of the right ear,—the movements are first in the head, then spread to the trunk, then to the lower extremities, then only to the side specially stimulated. In other words the reaction is at first *diffused* and then only becomes more special,—the hand is raised corresponding to the side stimulated. This mode of reaction holds true both in waking and sleeping states.

Boy twelve weeks old. I observed an interesting phenomenon which may be described as that of *associated movements*. The infant has both hands in his mouth. When one hand is taken away from the mouth the other goes off *simultaneously*, as if an invisible power has pulled it away at the same time.

Boy thirteen weeks old. When he was asleep, I tickled his left temple, he reacted with the left hand. Tickled his right temple, reacted with the left hand again. When the stimulus became more intense and prolonged, he moved his head, left hand and also the right hand.

I tickled the left foot when the boy was asleep, both hands reacted, the left hand having the start; I tickled the right foot, both hands reacted, the *left* hand having the start again.

Tickled the *left* temple; moved *right* hand; tickled *right* temple moved *right* hand again. *The reaction is indeterminate*,—sometimes it is bilateral and sometimes crossed. There actions do not conform to Pflüger's laws. On the whole *bilateral reactions predominate*.

When the child was asleep, I passed a pencil over the whole length of the left side of his face,—he reacted with the left hand first and then started with both. I passed the pencil over the right side of the face, he threw up both hands, the right having the lead.

Now and then one can begin to observe the manifestation of Pflüger's laws. When the child was asleep, I tickled his right foot; he drew away the foot. When the stimulalation is slight, the right foot alone reacted; when the

stimuli became summated he also reacted with the right hand. The same holds true, when the left foot is tickled,—on slight stimulations the left foot is drawn away; on continuous stimulation the left hand also reacts.

Reactions of four months' old babies and older conformed more and more to Pflüger's laws.

Experiments on older children give results of like character. Boy of seven years; when asleep, I tickled the right side of his face, the right hand reacted; I tickled the left side of face, the left hand reacted. When stimulations became summated or more intense the whole trunk reacted.

In experimenting on adults in the waking state the results are somewhat uncertain. When touching with a moistened object the right side of the face, for instance, and telling the subject to wipe it *immediately*, sometimes the right and sometimes the left hand reacts. One can often observe that when the subject reacts to sudden irritations, Pflüger's laws hold good; and sometimes one can observe reactions with the left hand alone, the *right hand being used for more differentiated movements.*

Experiments on adults, when asleep, almost entirely conform to Pflüger's laws of reflex reaction, especially is this the case, if the person has his hands free or sleeps on his back. In cases of hypnoidal states and hypnosis, the reactions are somewhat modified. If the subject happens to react with one hand, he *keeps on reacting with it.* Thus when the subject is touched with a wet or irritating object and is told to react, if it be the right side, he reacts with the right hand. If now the left side is similarly stimulated, the *right* hand keeps on reacting *crossing to the left side.* This takes place, even if there is a long series of stimulations,—the subject reacts with the hand he first starts to react with. This may be largely due to subconscious suggestion. I observed similar reactions in very suggestible subjects even in the waking state.

Manaceine's results are not confirmed by me, and still there is some truth in Manaceine's statement. Now I have suspected for some time that if the condition of limitation of voluntary movements is one of the important factors in the induction of sleep, we should expect that it

would not be a matter of indifference on which side we rest. We should expect that, if the right side is the more active, that the limitation of the voluntary movements would be more marked on that side. In carrying on my experiments on children and adults when in their sleeping states, I had occasion to observe that there was a *definite course in the motor reactions*, in the process of falling asleep. There is method in sleep. Some people go to sleep only on their back and find it difficult to fall asleep otherwise, while others who go to sleep on their side and who form the greater majority *always go to sleep on the same side;* there are very few who can fall asleep indifferently on either side. Moreover, my observations have shown me that by far the majority of *right-handed people go to sleep on the right side, while left-handed people go to sleep on their left side.* I further verified this interesting fact by statistical inquiry among my patients as well as among Harvard students. Some of the right-handed people who go to sleep on the right side may after some time turn to their left to change position, while others keep on sleeping on the same side through the whole night. The majority change position, the right-handed to the left and the left-handed to the right. More than *seventy-five per cent of right-handed* people have given records to the effect that they sleep on the *right side* or rather *fall* asleep on that side. Of the left-handed persons, I find only *one* out of *ten* who falls asleep on the right side. One case is specially interesting to quote: "Up to my seventh year I slept on my right side and I was right-handed. At about the age of seven I met with an accident, I was run over by a team and my right side was injured so that I could not use the limbs of the right side. I used my left hand only, I began to sleep on my left side. This I did up to my fifteenth year. I then began to practice with my right hand too and am now ambidextrous. I sleep now on either side. I use both hands."

Some claim that the reason why they sleep on the right side is because of the dreams produced by the pressure of the heart when sleeping on the left; but it is interesting to observe that others sleeping on their left write in their accounts that they cannot sleep on their right side, because

of the bad dreams, restlessness and nightmares produced. Some claim that it is simply a matter of habit, but the very fact that habit should give such a large percentage of right-handed, sleeping on the right side,and of left-handed,sleeping on their left side, points to a fundamental condition of our functioning activities and mode of rest. This condition we have found in the variability of our consciousness, by the ceaseless variations of the incoming sensory impressions from sense organs, muscles, joints and various other organic activities. The kinæsthetic sensations coming from the motor activities of our muscles and joints are very important in this respect. To bring about a state of rest and sleep, we must have the condition of monotony and limitation of voluntary movements, hence we can well see the reason why right-handed people whose right side is more active limit that side, while left-handed people prefer to limit the left side most active in them. We can also partly account for Manaceine's results, namely that in sleep, right-handed people react with their left hand which remains free as they sleep on the right side, while left-handed people react in sleep with their right hand, because they sleep on their left side. Manaceian's explanation is pointless in referring these reactions to the activities of the right and left hemispheres. According to Manaceine the left hemisphere of right-handed people is fatigued and hence in sleep the right hemisphere and the left hand have the ascendency. This explanation is fanciful and does not agree with facts. For when the experiments are carried out rigorously, *the reactions are found to conform, with the exception of very youn infants, to Pflüger's laws.*

Thus the experiments and observations made on lower animals, infants, children and adults all point in one direction, they point to the fundamental conditions of sleep, to monotony and limitation of voluntary movements. Taking as my motto the dictum "*hypotheses non fingo*" I strictly followed the logic of facts. Sleep is not so much due to merely cutting off sensory impressions, be they intense or faint, as to the *monotony* of sensory impressions which in fact may even be intense and numerous. It is the invariability of sensory impressions that reduces the organism to the passive state which we experience as sleep.

PART II

THEORETICAL

Chapter XII

Cell-energy, Threshold, "Stimulus-exhaustion" and Sleep

WE may advance in a tentative way the following theory which should be regarded as a provisional hypothesis of the causation of sleep.

One of the main characteristics of living protoplasm is its adaptability to the conditions of the external environment. External stimuli give rise to reactions of adjustment on the part of living substance. This property known in physiology as irritability is specially characteristic of all living matter or of what Huxley so aptly describes as "the physical basis of life." Verworn defines the irritability of living substance "as its capacity of reacting to changes in its environment by changes in the equilibrium of its matter and its energy." In other words, living tissue responds to external stimulations with some discharge of energy. The form of the discharge depends on the peculiar protoplasmic structure, according as it is muscle, gland, nerve cell or but slightly differentiated protoplasm, such as amœba or bacterium. The character of the reaction to stimuli depends on the state of organization of the living tissue.

The delicacy of response of living matter to external stimuli has its limit. Very weak stimulations do not call forth any reaction. Living tissue can only be set into activity by stimuli of certain intensity. If the stimulus falls below that intensity, the protoplasm does not react. This holds true of all cells, from the simplest bacterium and infusorium to the most highly differentiated muscle-cell or neuron. The minimal intensity below which the stimulus remains ineffective is regarded as the threshold of stimulation. As Howell puts it: "A stimulus too weak to give a response with a motor nerve is usually designated in physiology as subliminal; a similar stimulus with sensory nerves is frequently expressed by the equivalent term of subliminal, that is below the threshold, so a stimulus just strong enough to provoke a perceptible reaction is the

minimal stimulus for efferent nerves and the threshold stimulus for sensory nerves." "Exceedingly feeble stimuli" says Landois "are without effect. The degree of intensity of stimulation that originates the first trace of sensation is called the threshold of sensation or the threshold-value." The same is more clearly put by Verworn:

"Let us imagine an organism or part of an organism, *e.g.*, a muscle, under conditions in which no stimulus affects it, and let us bring to bear upon it a stimulus, *e.g.*, the galvanic current, which varies in intensity from zero upward and can be graded easily and delicately. Then we should expect the muscle to exhibit phenomena of stimulation, *i.e.*, to perform a contraction, as soon as the intensity is increased above 0. But this does not happen. The intensity can be increased considerably before the muscle performs even the slightest twitch. Only when the intensity has reached a certain degree does the muscle respond with a contraction; from here on the contraction is never wanting, and up to a certain degree becomes more energetic the more the intensity is increased. The stimulus, therefore, begins to operate only at a certain intensity, and this point is termed the *threshold of stimulation*. Below the threshold the stimulus is ineffective; above it the effect increases with the increasing intensity of stimulus. For the different forms of living substance the value of the threshold is very different. Thus, nerve-fibres are put into activity by extremely feeble galvanic stimuli, while *Amœba* demands very strong currents. The same is true of all other varieties of stimuli in relation to the various forms of living substance."

Psychologically we may agree with Stout that "the point at which it (the stimulus) is just indistinguishable,—so that the least increase would make it distinguishable is called stimulus-threshold."

Külpe's definition is short; "the just noticeable stimulus is technically termed the stimulus-threshold (die Reizschwelle)."

With the increase of stimulations the irritability of the living substance diminishes, the threshold rises. The same minimal stimulus will no longer bring about a reaction, the stimulus must be increased in intensity before any effect

can take place. Perhaps the best account of it is given by Verworn in his "General Physiology."

"If a living object be stimulated by long-continued, oft-repeated, or very strong stimuli, after some time it passes into the condition of fatigue. The general characteristic of fatigue is a gradual decrease of the irritability of the living substance. This is expressed especially in the fact that with increasing fatigue, the intensity of the stimulus remaining the same, the result of the stimulation becomes constantly less.

"We have already become acquainted with some examples of this fact in considering galvanic stimulation. If a constant current of average strength be passed through an *Actinosphærium*, at the moment of making, there begin to appear at the anode marked phenomena of contraction. The protoplasm of the pseudopodia flows centripetally until the latter are drawn in. Then the walls of the vacuoles break; and a granular disintegration of the protoplasm results, which proceeds constantly farther from the kathode during the passage of the current. This disintegration, beginning with great energy, becomes slower and less extensive the longer the current flows, and after some time is at a complete standstill. This means that the living substance of the *Actinosphærium* becomes fatigued in the course of continual stimulation, and decreases in irritability; hence the stimulus, which at first induced pronounced phenomena of disintegration, later produces no reaction at all. *Pelomyxa* is fatigued still more rapidly than *Actinosphærium*. Stimulation for a few seconds is sufficient to make individuals of this genus wholly non-irritable to currents of equal intensity; a much greater intensity is then required to call out the same reaction."

The principle of variability of stimulation is of great importance in the reaction of nerve-tissue. When the stimulus remains invariable, both in intensity and quality, no reaction follows. This is clearly brought out in experiments on nerve-tissue. "The electrical current" says Landois,[1] "exerts its strongest irritant effects upon a nerve at the time of its entrance into the nerve and at the time

[1] Text-book of Physiology.

of its disappearance. In like manner any rapid increase or decrease of the current passing through a nerve has a strong irritant effect. If on the other hand, the current be allowed to pass gradually into the nerve trunk or to disappear, or the current passing through the nerve be gradually increased or diminished, the visible signs of nerve irritation are much less marked. In general, the stimulation is most pronounced the more rapid the current-variation within the nerve, that is the more suddenly the strength of the current passing through the nerve is increased or diminished." This holds true in the case of the nerve, in which as Bowditch has shown there is little or no fatigue; where fatigue is present the principle of variability becomes a factor of the utmost consequence. The principle of variability of stimulation plays a very important rôle in cells in general, and in nerve-cells in particular where fatigue easily sets in and the threshold is raised with the continuation of stimulation and with the successive discharges of cell energy. Variability of stimulation and fatigue influence the fluctuations of thresholds.

It may be well to bring here the recent work of Sherrington in regard to the relation of neuron threshold and the discharge of neuron energy. Sherrington points out that among the characteristic differences between conduction in nerve-trunks and in reflex arcs (where nerve-cells are interpolated), we find in the latter "Irreversibility of direction instead of reversibility as in nerve-trunks, fatigability in contrast with the comparative unfatigability of nerve-trunks," and "much greater variability of the threshold of stimulus than in nerve-trunks." Sherrington points out that "in certain cases, especially in Invertebrata, observation (Apathy, Bethe, etc.), indicates that many nerve cells are actually continuous one with another. It is noteworthy that in several of these cases the irreversibility of direction of conduction which is characteristic of spinal reflex arcs is not demonstrable; thus the nerve net in some cases *e.g.* Medusa, exhibits reversible conduction (Romanes, Nagel, Bethe and others). But in the neuron-chains of the gray centred system of vertebrates histology on the whole furnishes evidence that a surface of separation does

exist between neuron and neuron. And the evidence of Wallerian secondary degeneration is clear in showing that that process observes strictly a boundary between neuron and neuron and does not transgress it. It seems therefore likely that the nexus between neuron and neuron in the reflex arc, at least in the spinal arc of the vertebræ involves a surface of separation between neuron and neuron" "In view therefore of the probable importance physiologically of this mode of nexus between neuron and neuron it is convenient to have a term for it. The term introduced has been *synapse.*" "At each synapse there is a neuron threshold. At each synapse a small quantity of energy, freed in transmission, acts as a releasing force to a fresh store of energy not along a homogeneous train of conducting material as in a nerve-fibre pure and simple, but across a barrier which whether lower or higher is always to some extent a barrier."[1]

Assuming then the principle of variability of stimulation of neuron energy and neuron threshold in regard to the liberation of neuron energy, principles advanced in my previous works, we can return to our subject under discussion, namely sleep. We may regard *sleep as a reaction of protoplasm* and as such we may express it in terms of *neuron threshold and neuron energy liberation.*

If a series of stimulations are kept up without variation, the sensory threshold gradually rises and finally the stimuli fall out of consciousness, they fail to awaken the psycho-physiological systems which have responded to the same stimulations before, because of the rise of the thresholds. This psycho-physiological law, characteristic of all tissues and psycho-neural systems, underlies the phenomena of sleep. As the cell or the neuron keeps on reacting to stimulations the disposable physiological energy becomes lowered and there is greater economy in the liberation of cellular or of neuron-energy. The cell or neuron does not respond to the same intensity of stimulus with the same amount of energy. In other words, *the threshold rises.* Should the stimulation keep on acting without variation, both as to quantity and quality, the threshold rises so high that the stimulus can no longer step over the threshold and

[1] Sherrington, "The Integrative Action of the Nervous System."

can no longer call forth any reaction in the cell. We say that the cell or the neuron is fatigued or exhausted. Really *this is not so much due to the exhaustion of the cell as to the exhaustion of the stimulus*, — it is the stimulus that has exhausted itself. Vary the stimulus in quantity or in quality and the cell or neuron reacts once more.[1] We may possibly best describe this general physiological fact of cellular reaction by the term of "*stimulus-exhaustion.*" By repetition the stimulus exhausts itself and can no longer call forth a reaction in the cell, although the cell may otherwise possess a large amount of disposable energy.[2]

As far as the particular stimulus is concerned the cell may be regarded as asleep. The stimuli are withdrawn. Putting the same general law in different terms we may say that *sleep is produced by monotony.*

The cell or the neuron may be regarded as a reservoir of energy. With the great biologist, Strassburger, we may describe the cell as "*energid.*" Conceived in terms of energy the cell possesses various levels of energy. The

[1] This may be related to the interesting experiments referred to by Sherrington:

"When the scratch-reflex elicited from a spot of skin is fatigued, the fatigue holds for that spot, but does not for the reflex as obtained from the surrounding skin. The reflex is then tired out to stimuli at that spot easily obtainable by stimulation two or more centimetres (half an inch) away. This is seen with either mechanical or electrical stimuli."

(*The Integrative Action of the Nervous System*, Sherrington)

[2] "The singleness of action from moment to moment thus assured is a keystone in the construction of the individual whose unity it is the specific office of the nervous system to perfect. Releasing forces acting on the brain from moment to moment shut out from activity whole regions of the nervous system, as they conversely call vast other regions into play."

"An arc under long continuous stimulation of its receptor tends even when it holds the common path, to retain its hold less well. Other arcs can then more readily dispossess it. A stimulus to a fresh arc has, in virtue of its mere freshness, a better chance of capturing the common path."

"This waning of a reflex under long-maintained excitation is one of the many phenomena that pass in physiology under the name 'fatigue.' Its place of incidence lies at the synapse. It seems a process elaborated and preserved in the selective evolution of the neural machinery. It prevents long continuous possession of a common path by any one reflex of considerable intensity. It favours the receptors taking turn about. It helps to ensure serial variety of reaction. The organism, to be successful in a million-sided environment, must in its reactions be many-sided."

(Sherrington, Address British Association for the Advancement of Science, 1904).

main levels of cellular energy have been described by me in former works as *dynamic*, *static* and *organic*.

By *dynamic* energy is meant that portion of energy which the cell can dispose of in its relations and reactions to the stimuli of the external environment.

By *static* energy is designated that portion of energy which is used only for the life maintenance of the cell, both in relation to other cells and to its own molecular constitution. It is the energy requisite to keep up its morphological organization and internal physiological functions.

By *organic* energy is meant the energy contained in the tissues of the dead cell not as yet decomposed into its inorganic constituents.

The levels of cellular energy are not different in kind. They merely represent progressive phases or stages of the same process of cellular activity.

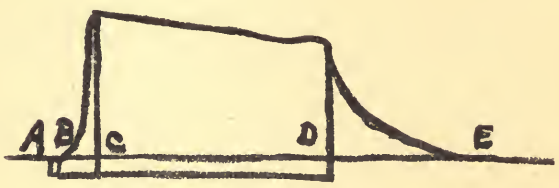
In its relations with the external environment, the cell does not utilize the whole of its dynamic energy. A large amount of it lies fallow, so to say, and remains inaccessible to the ordinary stimulations of the external environment. This amount of unused energy may be termed *stored, reserve energy*.[1] For the cell stores up energy as it stores food, in order to be able to meet the various emergencies that may arise in the course of its relations with the external world. In respect to storing up energy the law of stimulus-exhaustion may be regarded as a safeguard to the cell. The same qualitative stimulus cannot draw more than its allotted portion of energy. If the stimulation continues and attempts to draw more than its share the door, so to say, closes and the stimulus knocks in vain against a locked door. *The threshold rises with each successive stimulation.* When the *maximum* amount is drawn, there is no longer response to that particular stimulus, or rather to say, to that particular qualitative stimulation of a definite intensity. In regard to it the cell no longer reacts, — it is asleep. In order to respond again to the particular stimulus of a certain intensity and quality, the cell must recuperate its special form of energy. When this recuperation is effected, the cell is once more ready to react to the given stimulus.

[1] See my Studies in Psychopathology, Boston Medical and Surgical Journal, 1907.

The liberation of cellular energy in response to external stimuli may be regarded as the *active waking states*, while the restitution or passive rest-states of the cell, during which the threshold is raised and cellular recuperation takes place, may be regarded as *sleeping states*.

From the standpoint of cell metabolism, waking states are correlative with *katabolic* changes, while sleeping states are correlative with *anabolic* conditions. When the cell is active and awake, it liberates energy; when it sleeps, it stores energy. This process of storing up energy is going on all the time to some extent. If a stimulus of a certain intensity and quality keeps on liberating energy, it may arrive after some time at the *maximum*, when the threshold rises so high that the cell no longer reacts.[1] In respect to that stimulus the katabolic, active, waking state ceases and is replaced by the anabolic, sleeping states. The cell may thus be awake to all other stimulations, but in regard to the special stimulus it is asleep. We may say that the cell is *asleep partially*. When the liberation of energy has reached the *maximum* point, and the thresholds are raised

[1] "Whenever by a stimulus applied to an irritable substance, the potential energy there stored up is liberated the following phenomena may be observed: (1) A so-called latent period of variable duration during which no effects of stimulation are manifest; (2) A very brief period during which the effect of stimulation reaches a maximum; (3) A period of continued stimulation during which the effect diminishes in consequence of the using up of the substance containing the potential energy—*i.e.*, a period of fatigue; (4) A period after the stimulation has ceased in which the effect slowly passes away.



The curve drawn by a muscle in tetanic contraction, as shown in the diagram, illustrates this phenomenon. Thus, if AD represents the duration of the stimulation, AB indicates the latent period, BC the period of contraction, CD the period of fatigue under stimulation, and DE the after-effect of stimulation showing itself as a slow relaxation. When light falls upon the retina corresponding phenomena are to be observed."

An American Text-Book of Physiology, William H. Howell, Vol. II, p. 343.

in regard to most or to all the ordinary stimuli of the external environment, the cell may be said to be *fully asleep.*

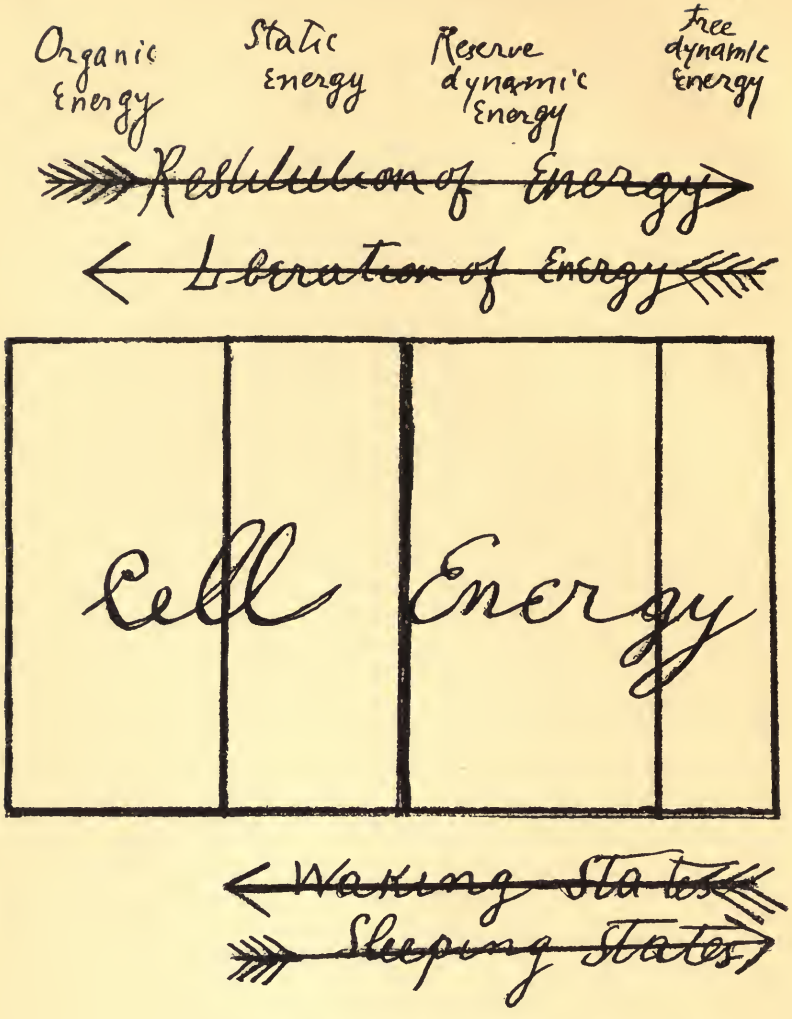
Should however, the liberation of energy by various stimuli keep on and begin to liberate the reserve energy levels and then pass over into the levels of static energy, the cell falls into a *pathological waking state.*

We may represent the relation of the different levels and their correlative states by the following diagram.

What is true of the cell holds also good of systems of cells and neurons constituting a multicellular organism. The condition of monotony and the law of stimulus-exhaustion play a very important rôle in the various changes and adaptations of life-activity. *Stimuli which have exhausted themselves by their monotony drop out and are replaced by new ones until the whole round of stimuli is gone through and the organism ceases to respond to its external environment, — falls asleep.*

The rise of threshold after stimulation holds true in the whole domain of biological activities. If the gastrocnemius muscle of the frog, for instance, is stimulated, say by an electric current, the muscle with successive stimulations responds less readily with contraction and this becomes more evident with the onset of fatigue. Pffefer in a series of extremely interesting experiments has shown that spermatozoids of ferns are attracted by malic acid, the progressive response of the attraction of the cell requiring a constant increase of the degree of the concentration of the acid, the increment of stimulations bearing within certain limits a constant ratio to the total stimulus. *The threshold rises with each successive stimulation.*

In the sphere of sensation we find the same rise of threshold. We are all acquainted with the fact that an additional candle or lamp, for instance, in well lighted room does not produce the same sensory effect as when brought into a more or less dark room. An electric light in the sun is scarcely perceptible. An additional ounce to a lifted pound does not feel as heavy as when raised by itself. A sound added to another sound or to a noise sounds less loud than when appearing isolated or when the same sound is breaking upon silence. The same relation holds true in the case of other senses.


Organic Energy
Static Energy
Reserve dynamic Energy
Free dynamic Energy
Restitution of Energy
Liberation of Energy
Cell Energy
Waking States
Sleeping States
Pathological
Physiological
Death
Morbid Reactions
Psychomotor Reactions to unusual changes of external environment
Psychomotor Reactions to habitual Environment

This same truth is still more clearly brought out in the fact that if we take a certain stimulus as a unit giving rise to a definite sensation, then as we progressively ascend and add more and more units of the same stimulus, the qualitative intensity of the sensation is far from rising proportionately. If we take for instance, the weight of an ounce as our unit of stimulation, then the successive moments of unit-stimulations, that is of ounces, will not give rise to as distinct and similar sensations as did the initial stimulation. The second ounce will give a sensation fainter than the first one and the third fainter than the second and so on until a point is reached, when the sensation of an additional ounce will not at all be appreciated, will dwindle away and almost reach the zero-point. In the same way, if the pressure of a gramme is excited in the hand, successive increments of grammes will not in equal degree increase the sensory effect. The additional increments of grammes, though they are equal units of stimulation, give rise to fainter and fainter sensations, until finally all sensory appreciation of the added unit fades away and disappears. If the hand is immersed in water say at the freezing point, an addition of ten degrees will be perceptibly appreciated, while successive increments of ten degrees each will be felt less and less and finally will not be noticed and will become difficult to detect. In short, the threshold rises with each successive stimulation.

To bring about a sensory response of an already stimulated sense-organ the intensity of the stimulus must be relatively increased. This is what constitutes Weber's law. The continuous progressive sensory response of a sense-organ requires a constant increase of stimulation which within certain limits, bears a constant ratio to the total stimulus.[1] This law is sometimes summed up by

[1] By noting for each strength of stimulus the addition required to evoke a just perceptible alteration of sensation, a series of quantities is obtained expressing the law according to which sensation alters when stimulation is increased. This expression is the so-called "law" of Weber. It says that a given stimulus is perceived less when added to a large than to a small one, or that an addition to a large stimulus is perceived less than an addition to a small one, unless it, relatively to the stimulus, is as great. The "law" may be phrased variously in physiological theory. It may be interpreted as not physiological at all, but psychological. The

physiologists and psychologists in the statement that the stimulus rises in a geometrical and corresponding sensation in an arithmetical progression, or as Fechner expresses it, " the sensation varies as the logarithm of the stimulus." We are probably nearer the truth, if we limit ourselves to the statement that " the increase of the stimulus necessary to produce a just perceptible difference in the sensation bears a constant ratio to the total stimulus." In short, *activity raises the threshold.* The phenomena fall under the law of stimulus-exhaustion. Each reaction to an external stimulus raises the threshold of that stimulus and with its repetition becomes finally excluded, temporarily, at least, from the cycle of *living* stimuli, that is, such as are capable of bringing about reactions and adjustments to the external environment. *The excluded stimulus is ignored, becomes non-existent for the organism. The organism is asleep for that stimulus.*

In the course of the daily activity of the individual the thresholds of sensitivity and of sensori-motor reactions in response to the stimuli of ordinary life rise gradually, the stimuli fall below the threshold of living reactions. The mass of stimuli of the external world constituting the external environment of the individual drops out of the life-cycle of the individual and for the time being ceases to exist for him. *The individual is asleep, asleep for that environment.* In other words the stimuli of the external world by their continuous action have become monotonous, have raised the thresholds and have become excluded from the life existence of the individual who is now deeply asleep for that given environment.

disproportion between increment of stimulus and increment of sensation may take place in purely psychological events and processes. Wundt is of that opinion. He points to the wide occurrence of such a ratio in all psychical activity as outcome of the relativity inherent in every conscious process. Waller finds the response in a nerve trunk directly stimulated, as judged by action current, increase much more nearly directly as the increase of external stimulus than does the response from muscle when nerve is stimulated, or from nerve when retina is adequately stimulated. Waller's evidence seems to point to the law being in part a function of the nerve-cell endings; probably, therefore, applicable to synapses as to motor plates. Delbœuf considers the law an expression of ever-increasing proportion of loss of effect in the central nervous system, due to "fatigue." (Sherrington in Schäfer's *Text-Book of Physiology*, Vol. II, p. 931.)

Should an appreciable variation occur in the environment at about the time when the organism is ready to fall asleep *the external world becomes again a living reality.* The individual becomes alive and wide awake to what is going on around him. If an appreciable change in the total mass or in some stimuli constituting the environment takes place, the individual may be awakened out of his sleep. Should the variation occur in some of the stimuli, their thresholds become lowered and the individual, though asleep in regard to all else, is awake in regard to them. This partial waking state is the soil in which dreams develop most luxuriantly. *We do not dream, when we are asleep, we dream, when we are awake.*[1]

The individual may be asleep to all else and still be awake to special stimuli whose thresholds are very low. The mother watching over her babe, the nurse, the physician attending their patients may be sound asleep to loud noises, but are alive and wide awake to the slightest changes in their charges. They have lost touch with the whole external world, but the ones cared for still have a firm hold on them. High as our bridges are raised for the whole world, they are low for the ones we care for.

Let an appreciable change occur in the stimuli to which we are awake, an amount of energy immediately is drawn from the reserve store, the thresholds barring the entrance to the host of intruders are lowered and we are once more in communication with the external world, — our sleep is gone and we are wide awake. *We can thus be wide awake in the very depth of our sleep.* The possibility of shaking off the grip of sleep under appropriate circumstances and especially the highly significant fact of wakefulness in the very depths of sleep form insuperable difficulties for all those plausible, apparently scientific theories of sleep, theories based on circulation, engorgement, anemia or hyperæmia, narcosis and autointoxication. We can watch in our sleep, count the flow of time and awake at the right moment. The fact that we can sleep and still watch and keep awake in regard to special objects and particular persons shows that sleep is not a matter of blood circulation

[1] My work on dreams will be published in a separate essay.

or of intoxication by accumulation of waste products in the system. Sleep is not a disease, not a pathological process due to the accumulation of toxic products in the brain or in the system generally. Sleep is not of those fatal uncontrollable onsets characteristic of the morbid processes, such as epilepsy, sunstroke, or apoplexy, nor is sleep a sort of narcolepsy. Sleep is not a disease, it is not, as the chemical speculators would have it, a kind of narcosis of the system by the poisons of fatigue products. *Sleep is not pathological, it is essentially physiological in character.* We do not go to sleep, because we are poisoned and wake up when the poisons are eliminated. We go to sleep at our own sweet will and can wake at pleasure. We can wake at any moment and can even be awake in the very depths of our sleep. Sleep is not an abnormal condition, it is a normal state. Like the waking states, *sleep-states are part and parcel of the life-existence of the individual.* Waking and sleeping are intimately related, — they are two different manifestations of one and the same life-process, — one is as normal and healthy as the other. One cannot help agreeing with Claperède's biological view that sleep is a positive function of the organism, that sleep belongs to the fundamental instincts. As Claperède forcibly puts it: "Le sommeil est une fonction de défense, un instinct qui a pour but, en frappant l'animal d'inertie, de l'empêcher de parvenir au stade d'épuisement: ce n'est pas parce que nous sommes intoxiqués, ou épuisés, que nous dormons, mais nous dormons pour ne pas l'être."

If we look at the matter from a psychological standpoint, we may say that sleep is a *rise of the thresholds of mental aggregates or of moments consciousness.* I have pointed out in a former work[1] of mine that to minimize the expenditure of neuron energy and reach the minimum of consciousness constitutes the tendency of psychomotor life. We can fully realize the importance of this tendency, if we regard it from a teleological point of view. In the struggle for existence or in the economical system of competition of modern life the saving of unnecessary expenditure, where only possible, is of the highest consequence. Organisms

[1] Multiple personality.

that can best effect such an economy of energy will be best fitted to survive. Those organisms that are enabled to reduce to its *minimum* the friction and loss of neuron energy have the advantage of possessing at their disposal a greater amount of energy to cope with new circumstances, with novel conditions, and react better and in a more favorable way when confronted with changes in their environment. This economizing becomes absolutely indispensable in the life-existence of higher organisms, the environment of which is highly complex. *The reduction of psychomotor activity to the least amount of psychophysiological expenditure, in other words, to the minimum of consciousness is the law of psychomotor life in general and of the highest representatives of that life in particular.*

I have further pointed out in the same work that this economizing is by no means an endless process, there is a certain minimum of consciousness beyond which psychic states cannot pass. This minimum of consciousness once reached, must remain stationary, for a fall below it is the arrest of the activity of the mental aggregate. In other words, there is a certain minimum below which consciousness cannot be reduced with impunity. Reduce the consciousness of the total psychic aggregate by lowering the sensibility of its constituents and the whole mental system will cease to function. Now under the conditions of monotony and limitation of psychomotor activity the *moment-threshold rises until the psychic minimum vanishes and the organism is asleep.*

Putting the matter again in teleological terms we may say that we go to sleep when we relinquish our hold on the relations of our external environment. We fall asleep when our consciousness is fagged, when we wish no longer to enter into communication with the external world, when we lose interest in our surroundings. When our interest in external existence fags and fades away, we go to sleep. When our interests in the external world cease, we draw up the bridges, so to say, interrupt all external communication, as far as it is possible, and become isolated in our own fortress and repair to our own world of organic activity and inner dream life. We fall asleep when the vital interests

in external being have fallen into the background of consciousness; we awake when those interests are aroused. When the struggle for existence ceases we repair to our castle and battlements. Sleep is the interruption of our intercourse with the external world; — it is the laying down of our arms for a respite in the struggle of life. Sleep is a truce with the world. When all psychomotor reactions to the stimuli of the external environment cease, we sleep. We sleep, because we are no longer interested to take an active part in the battle of life. From a teleological standpoint we may say that sleep is a dismissal of the external world with all its vicissitudes, troubles and pains. We cease to desire, we cease to react, and we sleep and dream in peace.

And when evening descended from heaven above,
And the earth was all rest, and the air was all love,
And delight, tho' less bright, was far more deep
And the day's veil fell from the world of sleep,

And the beasts, and the birds, and the insects were drowned
In an ocean of dreams without a sound;
Whose waves never mark, tho' they ever impress
The light sand which paves it, consciousness.

—*Shelley.*

Chapter XIII

Motor Consciousness and Sleep

THE condition of limitation of voluntary movements plays an important rôle in the induction of sleep states. This is due to the fact that motor consciousness not only forms the main body of our mental activity, but also that ideo-motor life is more subject to changes from slight stimulations than is our purely sensory life. Motor elements are highly plastic and modifiable; they enter readily into ever new combinations. From a biological standpoint one can realize the importance of the great modifiability displayed by sensori-motor and ideo-motor elements, since in the adaptation of the organism to its environment it is these elements that are mainly employed in reaction to stimuli of the external world. From the standpoint of adaptation a slight difference of sensory experience may give a widely different and highly complex motor reaction.

Psychomotor processes form the most important and largest portion of mental life. With the exception of man, all the representatives of the animal kingdom, from the lowest to the highest forms, represent but different stages in the evolution of sensori-motor life. The great majority of mankind still leads a life closely allied to animal sensori-motor states. Instance the delight of children in their plays, and the all absorbing interest of college students in their baseball and football games. Even in the highest and most developed forms of mental activity motor ideas and representations are by far the most predominant. Without motor elements ideational life is arrested. It is these sensori-motor and ideo-motor elements that constitute the " stream, the flow, the current " of our mental life. Motor elements enter freely and easily into combinations with all other elements of mental life.

This ease and high plasticity of ideo-motor elements is specially well brought out in hypnosis. Sensori-motor and ideo-motor suggestions are taken before purely sensory suggestions; paralysis, catalepsy, contracture, all kinds of

motor and kinæsthetic illusions and hallucinations are easily induced even in the very light stages, while it is only in the deeper stages that changes of ideo-sensory elements can be brought about. The induction of purely ideo-sensory illusions, hallucinations or delusions, positive and negative, can only be effected in the very deep stages of hypnosis. The freedom in forming new combinations and associations makes the suggestion of motor ideas and representations highly effective.

Throughout the scale of animal life, from the lowest to the highest forms, intelligence is intimately related to the degree of development of the muscular system and to the delicacy of motor adjustments. Among the lower forms of life the Cephalopods are well equipped with powerful muscular arms capable of executing a great variety of vigorous movements. Now the Cephalopods also possess a more highly developed nervous system with a higher grade of mental functions than the rest of the Mollusca. The great activity of ants and bees is notorious and their instinctive psychic life is the richest among the Arthropoda. Note the great variety of motor adjustments of the beaver and also of the intelligence that goes along with it. Birds possessed of a high degree of activity and motor adaptability are also the most intelligent of their kind, such for instance as the different species of talking birds. Notice the activity and great agility of the fox and also the unusual cunning for which the animal is so celebrated in song and fable. The suppleness of the dog, his quick reactions to stimulations, the resources of his motor adjustments and the great extent of his modifiability under changing conditions are all well known and along with them goes a high degree of mental activity. Of all the Mammals the Quadrumana are the most active, the most imitative, and with the exception of man, they are also the most intelligent. When we come to man we cannot help admiring the high complexity and extreme delicacy of his motor adjustments. Most marvellous however is the human hand, that divine organ which gives shape and form to works of art, to all outward visible manifestations of civilization. The great artists and thinkers of antiquity held the human hand in

great veneration. One of the great Greek philosophers did not even hesitate to declare that man's superiority over the brute was due to his hand. Finally in the wonderfully delicate motor adjustments of speech we find clearly illustrated the intimate relation between motor and psychic activities.

Experiments prove the same truth of the importance of motor elements in our mental life. If a series of syllables or numbers is given to memorize, after one reading, five out of ten can be remembered, though with some difficulty; but if the syllables or numbers are written down at the same time, though not looked at during the writing, a far greater percentage such as six or seven syllables can be remembered. If the motor elements in a train of ideas are suppressed, the order of the series becomes confused and even totally destroyed, showing that the motor ideas are important links in trains of association of ideas. *Motor elements form the nucleus of consciousness.*

Biologically regarded, voluntary activity, will, is the power of the organism to adjust itself to the conditions of the external environment. In its last psychological analysis voluntary activity, will, consists of ideo-motor elements, of various modes of adaptations. Will, consisting of kinæsthetic elements, constitutes the active subject of personality and individuality. If this be realized, then the vital importance of motor consciousness cannot be too highly overrated. *Motor consciousness is at the very heart of personality. We are what we can accomplish.* Extreme variability and adaptability of reactions to environment are the main characteristic traits of intelligence, will, personality.

The readiness of psycho-motor elements and groups to enter into ever new combinations gives rise to the formation of a great wealth of associations which help to make the labile psycho-motor groups and systems easy of recall. In fact it may be said that *the ease of recall is proportionate to the mass of associated kinæsthetic elements.* The great modifiability and variability of systems of motor elements requisite in the adaptation of the organism to the varying conditions of life, to its environment, make the ever greater

instability of motor elements an imperative necessity in the struggle for existence.

Forming the predominant elements, both as to intensity and mass, of the most complex, relatively stable, though ceaselessly shifting groups and systems, constituting the highly developed organization of mental life, the motor elements, presentative and representative, are also the first to become involved in the process of dissociation. In the various forms of nervous and mental diseases, under different conditions of intoxication and auto-intoxication, in the traumas caused by shock, physical and psychic, the delicate movements of adjustment are the first to become affected; dissociations of systems of motor elements are first to occur.

The instability of psycho-motor elements may be brought in relation with the fact of the early affection of muscular and kinæsthetic sensitivity and with the predominance of sensori-motor over purely sensory symptoms, so frequently occurring in the course of nervous diseases. With this may be correlated the significant fact referred to by Mosso that " all substances which slowly destroy the organism must produce phenomena analogous to those of curari since the motor nerves. . . . have less vitality than the sensory." It may also be observed in passing that cellular kinoplasm with the "kinocentrum," the centrosome and its archoplasmic structures, possibly the most primitive organoids of the cell, similarly manifest a high degree of variability and instability.

Motor elements may be regarded as the labile constituents of consciousness; — they become easily and frequently dissociated and dropped into the subconscious; but for that very reason they are also very easily reproduced or regenerated. In this respect motor elements follow the general biological law of organic regeneration: Organs that are easily and frequently lost in the struggle for existence are also easily regenerated, as for instance, the legs and claws of Crustacea or the tentacles of the starfish and the octopus. Dissociated systems of motor elements often become regenerated and under pathological conditions, when synthesis is impossible, they may recur with great persistence giving rise to the most uncontrollable types of

insistent ideas and impulses and to various forms of so-called "psychic epilepsy," especially of the motor type, closely mimicking typical organic epilepsy. Such dissociated, subconscious systems, like rudimentary, aborted organs, the appendix, for instance, may often prove very injurious to the organism. The recurrence of such subconscious, submerged, dissociated systems has its parallel in the biological phenomena of reversion or atavism.

The fact that psycho-motor elements enter easily into combinations and form extensive associative systems, makes them easy of recall and hence persistent in memory. From an educational standpoint one realizes the importance of this fact. Children learn things best not by abstract notions, not by looking at objects and hearing of things, but by acting out whatever is taught them. Motor consciousness is more vital than sensory. In the training of the mentally defective the best method followed is that of motor instruction, — to get at the meaning of things by means of action, even if it be automatic at first. As a matter of fact even the normal and well balanced mind gets at the meaning of things by handling them, by having the attributes and qualities of the objects and processes to be learned acted out. *Acting forms the greater part of man's life.*

Forming as motor consciousness does the very heart of mental activity, we can well realize the paramount importance of the condition of limitation of voluntary movements. By limiting the motor activity of the organism we impoverish its mental processes and lower the heart-beat of mental life. The active nucleus of psycho-motor reactions becomes passive, the organism becomes disabled in its response to the stimulations of the external environment, the thresholds rise and the organism is no longer in relation with the external world. When motor activity with its concomitant motor-consciousness becomes lowered, restricted, and fades away, the organism becomes necessarily passive and passes into sleep.

Thus monotony and limitation of voluntary movements work in one direction, — they tend to raise the thresholds of psychomotor reactions, they coöperate in the induction of sleep. These conditions are usually brought about natu-

rally in the course of the daily or nightly life activity of the individual organism, or the conditions may be produced artificially. In both cases the result is the same, — the organism falls asleep. In the life of higher animals the two cases may often combine. When the individual has fagged out his life interests in his active relations with his surroundings, when the stimuli have become monotonous to him and his activity with its correlative motor consciousness has become limited and lowered, he makes artificial arrangements for the intensification of the conditions of monotony and limitation of voluntary activity. He seeks for a dark nook, closes his eyes to exclude as much as possible all extraneous disturbing stimulations and tries to lie down quietly and comfortably, restricts his voluntary movements, breaks his connection with the external world and goes to sleep. *The organism falls into sleep, when the thresholds rise, wakes and rises when the thresholds fall.*

Looked at from a purely physiological standpoint and expressed in terms of energy, of the "cell-energy," sleep may be regarded as the onset of fatigue, as the onset of exhaustion of the levels of dynamic energy in response to external stimuli. The law of stimulus-exhaustion comes here into play as we have indicated in our discussion of cell-energy. Each particular stimulus has its maximum amount of energy which can be drawn upon, under ordinary conditions of daily life. As the special stimulus approaches its limit, it works under greater and greater difficulties, draws less and less energy and finally ceases to awaken any response,— the threshold is raised to its maximum and the organism, as far as that special stimulus is concerned, is no longer awake,— the organism is asleep. In the course of its daily activity the same takes place in regard to most of the objects, to most or to all of the stimuli that constitute the external world of the organism. The stimuli of the external world have drawn all that was permitted to them on their bank accounts, so to say, and the account for the time being is closed. Nothing more is permitted to go out. No stimulus of ordinary life is permitted to draw over and above a certain amount. There must always be ready capital for unusual situations, for emergencies. When the stimuli have drawn their due

and the organism is left with its reserve energy, — liberation of energy with its accompanying waking states ceases. The organism is no longer awake to the stimuli and is asleep.

As in the waking states the katabolic processes predominate, so in sleep the reverse processes, the anabolic, take the upper hand. The organism begins to recuperate its losses and fills up the accounts drawn upon by the stimuli of the external environment, when in active relation with them. With the increase of the income of energy the raised thresholds begin to fall until a point is reached when the stimuli once more overstep the lowered thresholds and once more gain access to the stores of life-energy, — the organism awakes and enters into active relations with the external environment.

Regarded then from various standpoints, sleep is a rise of moments-thresholds under conditions of monotony and limitation of voluntary movements. In this respect sleep strongly contrasts with hypnosis. In hypnosis the individual is specially accessible to any kind of suggestions coming from the external world, the psycho-motor reactions are greatly lightened and are released by the suggestion or external stimulus with great facility, far greater than in the waking state. This great facility is often expressed by the statement that in hypnosis the inhibitions are removed. What specially characterizes *hypnosis is the fact of fall of thresholds* present in individuals, with a predisposition to states of dissociation; in sleep, on the contrary we have found from our study, the general characteristic is the *rise of psycho-motor thresholds*. In passing from the waking state into the subwaking hypnoidal state the individual may either pass into hypnosis with its dissociated states and lowered psycho-motor thresholds or may go into sleep with raised psycho-motor thresholds. *The process of redistribution of thresholds takes place in the intermediary, hypnoidal states. When the redistribution of thresholds in the hypnoidal states brings about a fall of thresholds due to predisposition to and further cultivation of dissociations, the result is hypnosis; when the redistribution in the hypnoidal states brings about a rise of thresholds, the result is sleep.*

Biologically regarded, sleep is as much an instinct as hunger or sex.

Phylogenetically and ontogenetically, the sleep-states of higher animals are developed out of undifferentiated, intermediary, subwaking, hypnoidal-like states found in the resting states of the lower representatives of animal life. The hypnoidal state is the primitive rest state out of which sleep arises. Briefly put, the hypnoidal state is the germ of sleep.

Physiologically and psychologically regarded, sleep is an actively induced passive state in relation to the external environment; the psycho-physiological systems have their thresholds raised in relation to external stimulations; the rise of threshold is induced by a mass of impressions possessing little or no variability, by limitation or by relative withdrawal of stimulations, or what is the same, by monotony of stimulations and by limitation of voluntary movements.

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